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CYTOLOGICAL STUDIES ON THE ENTOMOPHTHOREAE.

II. NUCLEAR AND CELL DIVISION OF EMPUSA.

EDGAR W. OLIVE.

(WITH PLATE XVI[1])

THE division of the nuclei in Empusa has been found in the course of this investigation to resemble closely that described for Amoeba, Euglena, and other Protozoa. Such a primitive type of nucleus, which has been regarded as the typical protozoan form, has not so far been observed in the Metazoa, nor have any of the lower plants heretofore revealed a type of nucleus in which the "division-center" is permanently intranuclear. Such a type has been called by BOVERI (:00, p. 183) a "centronucleus," since it contains within itself a center of division which he assumes may be either in diffuse or concentrated form.

The varieties of protozoan nuclei and the types into which they may be conveniently grouped are discussed by WILSON (:00), by CALKINS (:01), and at some length by CALKINS in a recent article (:03); hence we may concern ourselves here mainly with those forms which appear to show nuclear conditions nearest those in Empusa.

SCHAUDINN published in 1894 an account of the division of the nucleolus-like body in the center of the dividing nucleus of Amoeba, and although he recognized that this appeared to play the chief rôle in nuclear division, he reserved, till further comparative studies, his ideas on the mechanical details of the process.

[1] As in this paper I shall have to refer frequently to the figures already published in *plates XIV* and *XV* which accompanied my foregoing paper on *The morphology and development of Empusa* (BOT. GAZETTE 41: 192–208. March 1906), I have numbered the figures on this plate consecutively with them.

BLOCHMANN ('94) and KEUTEN ('95) first described the division of the centronucleus in Euglena, and the latter author gave an interpretation of the function of the nucleolus, giving to it the name "nucleolo-centrosoma" (p. 219). According to KEUTEN'S observations, the nucleolus-like body of Euglena elongates in the prophases of nuclear division, and functions as a kind of spindle, which, however, appears to be solid and homogeneous, and not fibrillar as in the usual type of spindle. Other spindle substance and centrosomes, as well as "pole-bodies," the author could not find. The chromatin forms many chromosome-like bodies, which, after passing through an "equatorial ring" stage, are finally arranged in diverging daughter groups about the elongated axial strand of the nucleolo-centrosome. Just what the relation is between the dumb-bell shaped nucleolo-centrosome and the dividing chromosomes is not made clear in KEUTEN'S figures, although he asserts that this axial rod governs the entire process of nuclear division, since it orients the plane of division and since the chromosomes move along it. Whether this intranuclear body functions solely as an active fibrous mechanism for separating the chromosomes, or whether its poles have in addition the properties of centrosomes, are matters which should be more clearly determined before we can make comparisons with the conditions in Empusa.

BOVERI (:00, p. 182, note) suggests in this connection that the nucleolo-centrosome of Euglena is probably a concentrated and sharply individualized intranuclear spindle. CALKINS (:01, p. 265) further points out what he regards as an analogy existing between such a connecting rod in Euglena and the true fibrous spindle seen in higher forms.

SCHAUDINN (:00) has described a type of nuclear division in the sporozoan, *Coccidium shubergi*, parasitic in the intestine of a myriapod, which resembles even more closely that of Empusa. In the growing individual, according to this author, the nuclei divide a number of times, and finally, by a process resembling progressive cleavage, the body is cut up into many uninucleate individuals, which he terms merozoites. The division of the nucleus at this time is by a "primitive mitosis" (p. 230), totally unlike the double division which takes place in later stages, following the fertilization of the egg. The division in the first instance is quite similar to that of Amoeba and

Euglena, and also resembles very closely that in Empusa. The second kind of nuclear division is regarded by SCHAUDINN as still simpler, since centrosomes appear to be wanting entirely. The close resemblance of the latter type to certain division-figures in Empusa suggests, however, that the differences noted by SCHAUDINN may have been more apparent than real, and that poor fixation, due perhaps to the thickness of the membrane about the fertilized egg, may have been the cause for his failure to find the intranuclear centers in these cases also.

According to SCHAUDINN (p. 229), in the first mentioned division the chromatin granules gather in the center of the primary nucleus about a diffuse, slightly refractive substance, which stains less with haematoxylin than the chromatin. There results finally a globular central body, which he calls a karyosome, made up of two substances, plastin and chromatin. Upon the appearance of vacuoles within it, the karyosome grows larger, and it ultimately elongates to form a dumb-bell shaped central core to the dividing nucleus. At this stage the chromatin strands appear to radiate from the poles of the central body, differing in this respect from the corresponding nuclear figure of Euglena. The continued elongation of the central core is accompanied by the further massing of chromatin about the two daughter-halves of the central body, and the nucleus finally assumes a shape comparable to an hour-glass. In the slender connecting strand which unites the diverging nuclear halves there appears a peculiar *Zwischenkörper* which SCHAUDINN regards as probably a thickening of the fibrous strand which connects the halves of the karyosome. After the final constriction into two, the daughter nuclei, without entering upon a period of rest, begin immediately a second division.

While those members of the Entomophthoreae which live parasitically in the bodies of insects have attracted attention for more than a century, only a few investigators have published observations on the coenocytic character of the mycelium of these fungi. MAUPAS ('79, p. 252) records having seen many nuclei in the hyphae of *Empusa muscae;* while VUILLEMIN ('86) published drawings showing a similar condition in *Entomophthora gloeospora* Vuil. FAIRCHILD ('97) also mentions having noted the multinucleate mycelium in certain species of Empusa. BREFELD, who has studied the group

more than any other investigator, has noted also ('84, p. 41) that the hyphae of Conidiobolus, which grows parasitically on Exidia and similar fungi contain many nuclei; but he contributes no comment on the internal structure of Empusa, whose external characters and development he has described in great detail.

CAVARA next published ('99) some cytological observations on *Empusa muscae*, which was shown to have multinucleate conidia, and on *Entomophthora Delpiniana*, with multinucleate conidia; and he showed the importance of this character in delimiting the groups of the Entomophthoreae, a point with which I heartily agree. But CAVARA'S account of the division of the nuclei in these two forms by simple fragmentation is without doubt incorrect, as is plain from the complicated method described in the present paper.

Finally, GALLAUD (:05) has quite recently studied a form, Delacroixia, apparently similar in habit to Conidiobolus, whose mycelium as well as conidia contain numerous small nuclei.

The application of refined technique to the study of the cytology of these organisms has resulted in but one paper—that by FAIRCHILD ('97) on Basidiobolus—which deals exhaustively with the nuclear details. EIDAM ('86), who first discovered Basidiobolus and figured its uninucleate cells, and LOEWENTHAL (:03), both working with unsectioned material, and quite recently WOYCICKI (:04), have also contributed certain cytological observations in their studies on this form.

Basidiobolus shows, as we shall see, little resemblance cytologically to Empusa, and RACIBORSKI ('96) contends that it should not be included in the Entomophthoreae. However, since this form is generally considered in connection with the group, it seems best to review at this time FAIRCHILD'S account of the nuclear division in Basidiobolus. This author has described in great detail the peculiar division by which the two small beak-cells are cut off from the adjoining gametes. The division of the nuclei in these beaks bears little resemblance to that in Empusa, nor, indeed, to the process in any other thallophyte so far described; it rather resembles, according to FAIRCHILD, that in higher plants, in that a cell-wall is laid down through the instrumentality of a cell-plate. During the prophases of division, the nucleole disappears, and the author thinks it is probably used to form spindle

fibers. The nuclear membrane, as in the higher plants, appears to be dissolved and a barrel-shaped or cylindrical multipolar spindle is formed. Strongly staining granules terminate each of the poles of the broad spindle, and in the early phases, the many chromosomes gather in an equatorial plate. In the anaphases, a double row of granules appears in the equator of the spindle, which is regarded by the author as forming a true cell-plate, since the new cell-wall is laid down between them. It should be noted in this connection, however, that such a cell-plate appears to lack the earlier fusion of the fibers, which, in the higher plants, invariably precedes the splitting and the subsequent deposition of cell-wall substance between the two new plasma membranes thus formed. Vegetative nuclear division was also observed by FAIRCHILD, who evidently regards the process as essentially similar to that just described, although in this instance he did not succeed in finding a cell-plate.

WOYCICKI (:**04**), on the other hand, while agreeing with FAIRCHILD in general as to the events of mitotic division in Basidibolus, confirms RACIBORSKI'S assertion ('**99**) that the new cell-wall grows centripetally as a ring-formed growth, like that in Spirogyra, and in this case entirely independently of the spindle.

NUCLEAR DIVISION.

The nuclei in the coenocytic hyphae of Empusa are comparatively large, measuring frequently as much as 7–9 μ in diameter, and are thus especially favorable for a study of the phenomena of nuclear division. In the vegetative hyphae they are usually spherical when in a resting condition; while in conidiophores or in similar elongated cells the nuclei also often become greatly elongated. In the conidiophores of *Empusa* sp. (*figs. 23, 25*[2]), the resting nuclei may even assume irregular and apparently amoeboid shapes.

The resting nuclei of the vegetative hyphae of *Empusa sciarae* (*figs. 19, 27, 57*) have no nucleole-like bodies whatever, whereas in other forms, e. g., *E. muscae* (*figs. 38–40*) and *E. culicis* (*fig. 48*), each nucleus possesses one sharply defined nucleole. In still others, *E. aphidis* (*fig. 44*) and *Empusa* sp. (*figs. 22–26*), the number of nucleoles

[2]Figures numbered 1–48 will be found on *plates XIV* and *XV*. *Figs. 49–67* are on *pl. XVI*, herewith.

varies, since one, two, or sometimes even four such bodies may be normally present in a resting condition. In many cases where these structures do occur, they appear to be surrounded by a clear space, and some show a filamentous connection with the chromatin (*figs. 22, 44*). In other instances (*figs. 47, 48*), no such clear space is seen, but the nucleole appears instead to be closely surrounded by a mass of chromatin.

In optical sections, the nuclei of *E. sciarae* (*fig. 57*) show darker granules which are apparently connected by more lightly staining portions, thus giving an appearance corresponding to the common conception of the chromatin and linin in the resting condition. But careful focusing reveals rather a more or less homogeneous, much convoluted thread, or filamentous material. Since I cannot, in fact, see any appreciable differentiation into chromatic and achromatic portions, I am inclined to regard the chromatin in this instance as resting in the form of a spirem thread.

I am hardly prepared, however, to accept for these nuclei the ideas of VAN WISSELINGH ('99) and of GRÉGOIRE and WYGAERTS ('03), who think that there is no distinction between linin and chromatin. For, though it is true that in the resting nuclei of Empusa the nuclear material appears to be homogenous, during mitosis, on the other hand, some parts retain the stain much more tenaciously than other parts. One may bleach out an iron haematoxylin preparation, for example, until only that portion of the dividing nucleus immediately around the centers remains dark. However, whether this difference brought out by staining is due to mere physical causes, I cannot say.

Resting nuclei take the stain readily and are thus sharply differentiated; whereas those which are in a state of division stain less deeply. Hence in searching for division-stages, one has but to find those nuclei which are lightly stained and from which the color has been more washed out. But this applies apparently only to those nuclei which are somewhat advanced in the process, for such differentiation is not readily noticeable in very young stages. The earliest stages of nuclear division in the two species of Empusa in which I have studied the phenomenon, *E. sciarae* and *E. aphidis*, in fact are not altogether clear. It is to be hoped that other species will prove more favorable for the beginnings of the process. It is not quite clear, for example,

just what events are transpiring in such a nucleus as that figured in *fig. 49*. But from the later condition shown in *fig. 50* to near the close of the telophases, a great abundance of successive stages affords an easy interpretation of most of the events of nuclear division.

It is highly probable that *fig. 49* illustrates the early divergence of the two centers of division present in the middle of the nucleus, although no clew is given in the preparation toward the solution of the puzzling question as to the origin of these centers. In this figure a clearly defined strand connects two darker regions, where, presumably, nuclear material is being aggregated. A clear space, probably a cavity filled with nuclear sap, separates the two centers and encloses the connecting filament. Between *fig. 49* and *fig. 50* is plainly a large gap. In the latter, the two centers are large, conspicuous, intranuclear bodies, from each of which radiate in all directions granular fibers. These fibers appear to connect in some instances midway between the centers with those from the opposite system of fibers; others appear to cross over the equatorial region and to be independent of the other system.

Figs. 51–61 record successively the phenomena attending further divergence of the centers and the massing about them of the material of the divided daughter-halves of the nucleus. It may be noted in these preparations that one of the first evidences of the activity in a nucleus leading to division is the change from a globular to an oval form. During the progress of the internal mitotic changes, the nucleus finally becomes elliptical or oblong and greatly elongated. It may readily be noted also that the long axis of the dividing nucleus corresponds generally with the long axis of the filament. In some instances, however, the nucleus lies obliquely across the hypha, presumably carried about by cyclosis.

An increasing abundance of nuclear sap is shown in *figs. 49–58*. In *fig. 49*, the clear portion is seen to occupy the space between the two diverging centers. From the repeated occurrence of similar nuclei in which the middle appears to be occupied by a clear space, it seems probable that one of the earliest manifestations of mitotic activity in the case of Empusa is the accumulation of karyolymph in the immediate vicinity of the intranuclear centrosomes. In *fig. 50* the nuclear sap apparently lies both between the two centers and in the interstices

between the fibers. In *fig. 51* a clear space is noticed at one side of the dividing nuclear elements, whereas, in the more advanced stages shown in *figs. 52–55*, sap lies mainly between and separating the two active centers of division. In *figs. 54* and *57*, a region almost free from fibrous material separates the daughter halves and gives the appearance of a turgid, intranuclear, vacuolar cavity. It will be noted in these instances as well as in still later stages (*figs. 56, 58, 60*), that this nuclear fluid appears to exert pressure on the chromatic elements, as evidenced by the curved line where the massed chromatic material borders on the vacuolar fluid. In *fig. 56*, which shows the next step in the division of the nucleus following *fig. 57*, the cytoplasm has constricted in two the mother-cavity, and in this figure as well as in the similar stages shown in *figs. 58, 60*, it will be at once noticed that the solid constituents of the young daughter nuclei occupy a pseudosynaptic position, and that the greater part of the cavity of the daughter nucleus is occupied by a clear space. Whether an osmotic pressure of the intranuclear fluid causes this appearance, or whether it is due simply to the massing or contraction within the nuclear cavity of the chromatic elements about the polar centrosomes, can hardly be determined with certainty, but it is probable that both forces are thus operative.

Fig. 58 illustrates an interesting deviation from the more common median constriction of the elongated nucleus shown in *figs. 56, 59, 60*. Here a double cytoplasmic constriction has taken place, resulting in two daughter nuclei and between them a vacuole, which is undoubtedly filled with sap from the mother-nucleus. Probably in this instance the dividing nucleus became so greatly elongated that surface tension operated in such a way that the encroaching cytoplasm constricted it into three parts instead of two, as is usual.

In *fig. 59* is shown an early telophase condition in which the solid constituents of the nucleus are being redistributed throughout the daughter nuclei. Here the movement of chromatic material, as is characteristic for nuclei in this condition, is opposite to that seen in early stages of nuclear division. Whereas in the early phases this material moves toward and masses about the polar center, in the teleophases, it moves in the opposite direction, away from the center. In *fig. 59* the center in each nucleus is still conspicuous, although a

considerable portion of the mass, especially that in the upper daughter nucleus, has moved centrifugally, towards the nuclear membrane. We note also in the upper nucleus of this figure what appears to be a thickening at the outer ends of the radiating filaments, and in the lower nucleus some of the radiations are seen to be double.

I am inclined to interpret *fig. 61* as a very late telophase, and as a near approach to a resting nucleus; between this figure, however, and *fig. 59* there is obviously a wide gap. Such nuclei as that shown in *fig. 61* are comparatively common, however, and without doubt represent a stage in which the center now exists only as a focal region for the attachment of the chromatic fibers to the nuclear membrane. Occasionally one may see at this focal point, especially in preparations stained with the triple stain, a very dimly defined body, apparently a remnant of the old center, lying against the nuclear membrane. But in similar preparations stained with iron haematoxylin, the core of the old center seems to be entirely empty, while immediately around it a dense chromatic mass persists for some time. In *fig. 61*, for example, there remains hardly any visible evidence of the old center of division; a few conspicuous fibers and a darkly stained mass which was accumulated about the center remain, however, to mark its former position, and the fibers now serve apparently to attach the main mass of chromatin to the nuclear membrane.

Apparently such a nucleus is "polarized," at least in so far as there seems to be a special and possibly permanent focal point on the nuclear membrane for the chromatic materials. Whether this is centralized in the same sense as Euglena, or permanently polarized, as in the case of Phyllactinia (HARPER, :05), must be settled by further investigation.

We see that, from very early stages, the centrosomes in these dividing nuclei are conspicuous bodies, which grow larger and more conspicuous as division progresses, and this is due, in my opinion, to the accumulation of nuclear materials about them. Each centrosome is lighter in the middle and has a darker rim (*figs. 50–67*), a phenomenon which I am convinced is partially due to refraction. But careful washing out of the stain sometimes leaves the middle totally bleached out, while immediately around it some parts retain the stain. Each centrosome thus appears possibly to have a core of plastin and a rim of chro-

matin, as is claimed by SCHAUDINN for the similar bodies of Coccidium. *Fig. 61* could therefore be interpreted as showing the rim of chromatin, but the plastin substance of the middle core has entirely disappeared.

The division of the nucleus just described for *Empusa sciarae* takes place in the later vegetative stages, when cross partitions are frequent and when the coenocytic cells are consequently comparatively short. Among the four or five nuclei present in each cell in this condition, we may occasionally find two nuclei in a state of division; generally but one, however, divides at a time. The nuclei in a certain cell do not, therefore, divide simultaneously, but each appears to act in entire independence of neighboring nuclei.

There occurs in earlier stages of the vegetation of the fungus an interesting modification of the process as described above. *Figs. 62–65* illustrate late stages in the division of the nuclei found in long coenocytic cells, in which cross-partitions are few and far apart. It will be remembered that during the earlier vegetative activities of *Empusa sciarae*, nuclear division takes place much more rapidly than cell-division, with the result that septa occur at rare intervals, while, on the other hand, nuclei during this period are abundant. When we come to compare the seemingly different type of nuclear division shown in *figs. 62, 63* with that shown in *figs. 50–55*, we note in each the intranuclear centers and the radiating chromatic filaments mentioned above. But here in the latter type the dividing nuclei assume an hour-glass shape, similar to those of Coccidium as shown in certain of SCHAUDINN'S drawings, instead of the oval or elliptical shape characteristic of the nuclei during the division above described. A careful comparison, however, leads to the conclusion that the only essential difference between the two types of division is in the amount of nuclear sap. In the latter case there is lacking the clear space filled with nuclear sap, between the separating chromatic filaments, so conspicuous in the type above described; or at least the fluid is much diminished in quantity. In *fig. 65* some is still present in the constricted region; but between the separating daughter halves in *figs. 62, 63*, as well as in *fig. 64*, little sap, if any, is evident. *Fig. 65* shows, in fact, a transition between the elongated, hour-glass shaped nuclei of the latter type and the oval ones of the former.

There can hardly be any doubt, especially after we make comparative observations on *Empusa aphidis*, which has a similar type of nuclear division, that such stretched-out nuclei as are shown in these figures get their peculiar form from the currents of protoplasm flowing in these long coenocytic hyphae. Resting nuclei, as is well known, are plastic to a remarkable degree, and thus, in long cells, may frequently become much elongated; so it seems more than probable that these dividing nuclei may likewise become stretched out in the same way.

Figs. 66, 67 represent poorly stained nuclei of *Empusa aphidis* in which division is taking place in a manner evidently similar in every respect to that described above as the second type. Here too we have vegetative hyphae in which septa are few and far apart; hence the general protoplasmic movements must disturb considerably the dividing nuclei. Practically all of the nuclei of this species conform to the type shown in *figs. 66, 67*, for I have but once found a doubtfully elliptical nucleus. The fact that the second type of division alone occurs in the long tubular filaments of *Empusa aphidis* points therefore to the conclusion that the stretching out of the dividing nuclei in these instances is brought about by cyclosis. In this second type of division here described, we can readily imagine that the protoplasmic currents also assist materially in the constriction and final separation also of the halves of the dividing nucleus. We may thus conceive, in the one case, of the protoplasm as undergoing such limited movements on account of its confinement in a short cell, so that the dividing nucleus is but little disturbed, and consequently, by the accumulation of karyolymph, it assumes a short oval or rounded shape; whereas in instances where the cells are long and the protoplasmic currents therefore stronger, the dividing nuclei become drawn out and elongated, and constriction becomes very early evident.

In *figs. 64, 65*, we note an interesting phenomenon. Here occurs an infolding at the poles, giving an appearance as if some stress had indented the nuclear membrane at this point. I have not observed this phenomenon in the oval nuclei of the first type, but it apparently occurs not infrequently in nuclei of the second type. It is possible of course, that the infolding may be an artifact, caused in some manner by the reagents. Such cases furnish indisputable proof, at any

rate, that the intranuclear centers are strongly anchored to that nearest portion of the nuclear membrane situated poleward from them.

We may summarize these results pertaining to the nuclear division of *Empusa sciarae* and *E. aphidis* as follows. During the early stages of division the nuclei become less stainable and slowly change from a rounded to an oval shape. Two diverging centers of division, or centrosomes, become conspicuous near the middle of the nucleus. Fibers may now be seen radiating from the two intranuclear centers, some crossing the median line between the centers, others evidently anastomosing with fibers from the other system. The nucleus elongates still more and the opposed centers, each with its system of radiating fibers, diverge farther and farther apart. The centrosomes appear to increase in size as division proceeds, probably from the aggregation about them of the chromatic material in the radiating fibers.

In cells which are comparatively short, a space filled with sap is early apparent between the diverging daughter masses, as well as in the interstices between the chromatic fibers. This sap increases in amount until in the oval, turgescent nuclei found in such short cells, the middle portion becomes filled with it, and we note a clearer central part, containing at first a few scattered fibers, separating the two polar, darkly-staining regions. On the final withdrawal of the last chromatic filaments to the daughter-poles, the middle of the elongated nucleus becomes perfectly clear and transparent. The cytoplasm now encroaches on the median sap-cavity and, by constriction, cuts the mother-nucleus in two. In some instances, a double cytoplasmic constriction may take place, so that a vacuole filled with nuclear sap is cut off and left between the two daughter-nuclei.

In long cells, on the other hand, or in filaments with few, far-separated septa, the nuclear sap does not accumulate in the manner just described; hence the nucleus, instead of becoming turgid with the liquid secretion, becomes early in the process of division constricted in the middle and greatly elongated, thus assuming the shape of an hour-glass. A few connecting strands in the constricted portions remain for some time, while the active polar regions, with their dense accumulation of chromatic material, become separated farther and farther, with the result that the two daughter-halves are finally pulled apart.

The lack of accumulation of nuclear sap in the latter type of nuclear division constitutes the only difference between this type and the one described above.

The accumulation of sap in the nucleus in the first instance is probably due to the lack of disturbance of the process by the restricted protoplasmic currents in the short cells. The lack of accumulation of sap in the second instance is probably due to the disturbing influences of the stronger protoplasmic movements which undoubtedly take place in the long tubular filaments. In the first type the chromatic substance in the newly formed daughter-nuclei comes to lie in a mass at one side of the nuclear cavity, thus resembling somewhat a synaptic condition. In the other, the nuclear materials of the young daughter-nucleus, massed about the centrosome, are closely enveloped by the surrounding cytoplasm, and not until later in the reconstructive processes which follow, does the nuclear sap appear.

Towards the close of division, the center in each nucleus comes to lie close to, if not actually on, that portion of the nuclear membrane nearest the pole. Its attachment and anchorage to the nuclear membrane is proven by the frequent indentation of the membrane at this point. In the young nucleus the center remains conspicuous for some time, but finally, with the resumption of a resting condition, it becomes entirely lost to view. In the resting nucleus, the nuclear materials appear to be distributed more or less evenly on a much convoluted, seemingly homogeneous, filamentous thread which resembles a spirem.

We have now to emphasize, before entering upon a discussion of the general bearing of these facts, certain peculiarities at once noticeable in this primitive mode of nuclear division. In the type first described, the nuclear membrane plainly persists throughout the whole process of division; also in certain nuclei of the elongated type, it undoubtedly persists (*figs. 65–67*), although it is here not so conspicuous. I am inclined further to regard a membrane as present around the chromatic fibers in *figs. 62–64*, notwithstanding the fact that in the preparations it cannot be seen. The iron haematoxylin stain is probably accountable for the failure to bring out the membrane clearly in this instance. Hence we may record at this point that in the case of Empusa, the nuclear membrane is at least usually persistent through-

out the whole of nuclear division, and that, consequently, the entire process is intranuclear.

Secondly, we note the absence of any definite chromosomes in this peculiar division; and equally noticeable is the failure of the chromatic material to become aggregated into an equatorial plate, as well the want of a definite achromatic spindle. Careful counts, however, of the fibrous strands radiating from the centrosomes indicate the probability of a constant number of these chromatic fibers. I have in many instances counted about sixteen of these radiations from the polar view (*fig. 55*), but it is perhaps impossible to determine exactly the correct number, on account of the great confusion of threads. I believe, nevertheless, that these fibrous strands of chromatic material represent the chromosomes, and further, that the two daughter nuclei each receive an equal number.

There seems little evidence for the existence of a differentiated achromatic spindle, but further study in related species may possibly assist in determining what here may correspond to such a structure. It is true that in *fig. 64* is shown an indefinite, intrafibrillar substance which might be taken for a spindle, but I am convinced that the thickness of the section in this instance is responsible for this misleading appearance. Careful observation reveals chromatic fibers in a lower plane of focus and it is their great number and close proximity in the background that probably causes the indefinite, washed-out appearance between the sharply defined filaments. In *fig. 54* also there is shown a similar substance between the radiating fibers, whereas in *fig. 55* this is not so noticeable. *Fig. 50* as well shows but little nuclear substance other than that in the sharply defined chromatic fibers radiating from the two centrosomes.

Since all the dividing nuclear substance outside the centers is apparently confined to the two systems of filamentous structures radiating from the centers, we must therefore conclude that there is no intrafibrillar spindle-substance. And, since we see also that these radiating strands appear to be chromatic in their staining reactions and not achromatic, the only conclusion which seems possible is that there is no substance in the dividing nuclei of Empusa which can correspond to an achromatic spindle. I am not prepared, however, for such an extreme belief, which would obviously much belittle the

importance of a fibrous mechanism for the accomplishment of mitotic division.

I should prefer to believe that the achromatic spindle substance, probably present only in small amount, is a part of, and inseparable from the deeply staining radiations. Should this be true, then we may conclude that the kinoplasmic spindle-mechanism is bound up closely with the radiating parts corresponding to the chromosomes. Possibly the chromatin is here more nearly a liquid substance than is usual, hence it may diffuse more readily throughout the linin basis, so as to be indistinguishable from the latter. At any rate, I should regard the chromatic filaments radiating from the centrosomes as corresponding in part to the fibers of the more differentiated spindle of higher organisms; and, further, since these mark the paths of the chromatin, they must also correspond to the mantle fibres. In the case of Empusa, so far as studied, there is obviously nothing which can correspond to the central spindle of more complicated nuclei.

CELL-DIVISION.

Cell-division in Empusa, as in many other lower plants, takes place in entire independence of nuclear division, and also apparently remote from nuclear control. There is concerned in the process no such fibrous structure as a cell-plate; since, in fact, no cell-plate is ever formed at the close of the nuclear division described above. Further, cell-division may not take place till long after all division of the nuclei has ceased; hence coenocytic hyphae result.

The branched conidiophores of *E. sciarae* (*figs. 16, 18*), as well as conidia in the process of abstriction (*figs. 28, 30, 31, 36*) furnish especially fine material for the study of cell-division. Examples are also occasionally met with in sections of vegetative hyphae (*figs. 19, 21*). A striking feature of the process as seen in conidiophores and young vegetative hyphae is the fact that in the cleavage of the cell, the new ring-formed partition-wall grows across a wide vacuolar space. In the case of the abstriction of the conidia, on the other hand, and probably as well in older vegetative stages, although I have not as yet seen the phenomenon in the latter instance, the new wall grows through a mass of cytoplasm. *Fig. 18* shows clearly the method of growth progressively inward of the ring-formed septum.

The plasma-membrane which bounds externally the thin primordial utricle has evidently been infolded at this point, thus forming a deep, narrow furrow. The young partition-wall which is being deposited in this groove can not be seen in the figure. We note further in *fig. 18* that the two nuclei which are shown are in a state of rest; in fact, nuclear division does not occur at all during the pre-fructifying period characterized by the formation of conidiophores. And in the same figure we also see that the nuclei are separated by a wide vacuolar space from that part of the cell in which division is proceeding, and that they are joined to the active region only by a narrow cytoplasmic connection. It seems reasonable to suppose that cell-division, in this instance, is a cytoplasmic phenomenon and is merely remotely or indirectly subject to nuclear control. In *fig. 18* it will be noted that the stain is deepest at the inner margin of the cleft, showing that in this innermost region in which the new wall is being laid down, the cytoplasm is densest and most active.

Fig. 19 shows a similar ring-formed septum partly across a young vegetative hypha, at a slightly advanced stage of growth. A bridge of cytoplasm is next thrown across the vacuolar space before the wall is completely formed, as is seen in *fig. 20*. This figure brings out most clearly the region of greatest activity. In the preparation, the stain (iron haematoxylin) was well washed out, so that the cytoplasmic bridge as well as the ring-formed wall are left unstained except at the innermost part of the furrow, where a small black granule is conspicuous. In this dark region the new wall is evidently being deposited. Immediately on the throwing across of the cytoplasmic bridge, the greater turgor of the cell below ordinarily causes the partition to bend outward toward the outer end of the hypha (*fig. 20*). This bending is also quite noticeable after the final completion of the partition wall (*fig. 17*).

A study of these figures might lead to the conclusion that we have here a process exactly similar to that already described for certain other fungi (see HARPER, '99, p. 506), in which the cleavage furrow first cuts across the cell and the wall follows later. One would in fact naturally come to this erroneous conclusion, since every one of the drawings mentioned above, except perhaps *figs. 19, 21*, shows clearly the circular furrow, but no sign as yet of the ring-formed septum.

In these preparations, however, the thin, delicate walls are not at all easy to differentiate. I am convinced that, unlike the cases just referred to, in Empusa a delicate wall grows simultaneously with the cleavage-furrow and not later. The figures which show abstriction of the conidia furnish sufficient evidence for this conclusion. In this case, the process of abstriction takes place essentially like the cell-division described for conidiophores, except that here the cleavage-furrow grows through a mass of cytoplasm instead of through a central vacuolar space. In *fig. 38*, the completed wall separating the conidium from the basal cell of the conidiophore may be plainly seen, since the protoplasm is shrunken away on both sides. But in *figs. 28, 30, 31, 36*, although the cleft itself at the base of the conidium is brought out with diagrammatic clearness, the wall which accompanies it is not so evident. Two reasons may be noted here, however, which are not so apparent in the case of conidiophores, for the conviction that the partition-wall is also present in these instances. The wall which cuts off the conidium, when completed, as was noted above in the case of the newly formed septa in conidiophores, is forced upward by the greater turgor of the basal cell, and here forms a kind of columella within the conidium. While it is possible that the cleavage-furrow itself might be stretched and forced upward in this fashion, yet it is more than likely that the unsupported plasma-membranes bounding the cleft could not withstand the considerable pressure which is developed. A further reason for the belief in the necessity of the cooperation of a ring-formed wall in these instances is seen in the shooting off of the conidia immediately on the completion of their abjunction. In *figs. 29, 37, 43*, are shown conidiospores which have evidently just been shot off and in which the turgescence of the protoplasm has now reversed the position of the cross-wall, making a papilla at the base instead of an indentation. We see clearly in *fig. 37* the delicate wall shrunken away from the spore-plasm. An uncompleted wall at the time of the discharge of the conidium would evidently allow the escape of the protoplasmic contents.

GENERAL DISCUSSION.

It is clear that the division of the nuclei of Empusa which has just been described, although apparently resembling in some respects

amitosis, is certainly much more complicated than a mere mass division such as occurs in the latter process. In the division of the centronucleus of Empusa, we have, as was seen, intranuclear centers of division, or centrosomes, which function as active agents in nuclear division. Centrosomes, when they do occur, are, on the other hand, supposed to take no essential part in amitotic division. In the dividing nuclei of Empusa, we have also, besides active centrosomes, an arrangement of the chromatin in radiating fibers comparable to chromosomes, and, further, a simple spindle-apparaatus. I should therefore separate the process in this form far from amitotic division, although still regarding it as an extremely simple type of mitosis.

In the division of the nucleus in Euglena, the resemblance of the phenomena to amitosis was regarded by KEUTEN as so striking that he called the process in this organism a simple intergradation between direct and indirect division. In the case of Coccidium SCHAUDINN remarks that the division of the nuclei takes place by a "primitive mitosis." Should SCHAUDINN be able to find, further, as is probably possible with improved fixation, the division-centers in his second kind of division, which occurs in the stages following the fertilization of the egg, he should come to the conclusion that he has here also not, as he concludes in his paper, a still simpler type than the first, but a primitive mitosis essentially like the first. For in the event of similar intranuclear division-centers occurring in both cases, he would have two types of division somewhat comparable to the two types mentioned above in Empusa, which, as we have seen, differ from each other only in the amount of nuclear sap present, and in the earlier constriction and elongation of the second type.

In Empusa, Coccidium, and Amoeba, the absence of an arrangement of the chromatin during the prophases of nuclear division in an equatorial plate, attests the extreme simplicity of the mitotic process in these instances. The absence of this equatorial arrangement leaves us, in fact, unfortunately in doubt as to the manner of the equal distribution of the chromatin between the two daughter nuclei. If we accept, however, the commonly accepted doctrine that "the daughter nuclei receive precisely equivalent portions of chromatin from the mother nucleus" (WILSON, :00, p. 70), we must conclude

that this equal division of the chromatin occurs somewhere in the obscure prophases; in Empusa, e. g., probably long before the appearance of the conspicuous centers seen in *fig. 50*.

The absence of the arrangement of the chromatin into an equatorial plate prior to the divergence of the two daughter masses possibly results from the poor development of the achromatic spindle, due to the small amount of linin present in the nucleus. To this same cause is probably due also the failure to form definite chromosomes in these simple organisms. In Amoeba, according to SCHAUDINN'S observations ('**94**), there are apparently no radially arranged chromatic filaments; while in Coccidium (SCHAUDINN, :**00**) and Empusa, evidently a still higher type obtains, since in both these instances we have formed, rather late in division, filaments of chromatin, which undoubtedly correspond to the chromosomes, and are radially arranged about the centrosomes.

The formation of an "equatorial ring" in the nuclear division in Euglena, and of a more compact equatorial arrangement of the chromatin in Euglypha (SCHEWIAKOFF, '**88**), Actinosphærium (HERTWIG, '**98**), Paramœcium (HERTWIG '**95**), Aulocantha (BORGERT, :**00**), and other Protozoa, certainly indicates the presence in these forms of a more highly differentiated mechanism for the halving of the chromatin. In all these cases, we note the early formation of chromosomes, which are usually very clearly defined, and generally a well developed spindle, consisting of both central spindle as well as polar mantle-fibers; so that we are justified in the conclusion that in these more highly differentiated figures there is a greater amount of intranuclear achromatic substance present than in the nuclei of Empusa and Coccidium.

We may compare at this point the degree of differentiation of the intranuclear spindle in these organisms. KEUTEN regards the dumbbell shaped nucleolo-centrosome in Euglena as probably serving as a spindle mechanism; and BOVERI (:**00**) and CALKINS (:**01**, :**03**) also think that the strand of connecting substance in this constricted nuclear body corresponds to the central spindle of higher organisms. CALKINS (:**01**, p. 265) points out in this connection that Paramoecium furnishes a clew to the relationship of such connecting strands in Euglena to the fibrillated central spindle, since in Paramoecium the

"central portion of the division-figure is a single strand which widens and becomes fibrillated at the ends." SCHAUDINN (**'00**, p. 229) evidently does not so regard the corresponding portion of the dividing nucleus in Coccidium, since he calls this connecting strand simply "Verbindungsfaden der Tochterkarysome," and says that "von Spindlefasern und Poldifferenzirungen ist keine Spur wahrzunehmen." I am also inclined to believe that no part of the constricted nucleolar body in Euglena and Coccidium is homologous with the central spindle of more complicated nuclei, since in all cases where a structure occurs which can be positively referred to the central spindle, it consists of usually distinct fibers which extend between and connect the diverging chromosomes. In these instances, the connecting portion of the dividing nucleolar body bears no such relation to the chromatic filaments, but instead it lies simply as a slender core in the axis of the mitotic figure. Further, in the centronucleus of Empusa, which is undoubtedly similar in every respect except this one to that of Coccidium, such a connecting body does not occur at all, unless, indeed, it be represented in *fig. 49*. Therefore, the strand connecting the constricted nucleolo-centrosome of Euglena and Coccidium, in my opinion, does not represent, phylogenetically, the central spindle, nor in fact any structure of the higher nuclei, but is a structure which is confined, so far as yet known, to these two Protozoa. It is just what SCHAUDINN calls it, viz., simply a drawn-out filament connecting the daughter centrosomes, which has no apparent function. On the other hand Paramoecium, as shown in HERTWIG'S figures, shows a true central spindle, and the final median constriction of this spindle and the consequent aggregation of the fibers of the middle portion into what appears to be a single strand, does not present a figure which can be in the least compared, as CALKINS claims, with the nucleolo-centrosome described above. If there be any indication at all of central spindle in these simpler centronuclei, then, in my opinion, it must be looked for in the dimly defined, continuous, bluish substance, for example, shown in the drawings of Coccidium (see SCHAUDINN'S *figs. 31, 32*), which lies between the daughter chromatin masses. SCHAUDINN himself, however, evidently believes that these are not spindle fibers. In the case of Euglena, the central spindle is probably represented by the dim

achromatic substance remaining between the separated chromosomes, e. g., in KEUTEN'S *fig. 11*. But in Empusa, there is no appreciable achromatic substance in the corresponding equatorial region of *figs. 62, 67*. There is, therefore, according to my interpretation, in the simple cases where no equatorial arrangement of the chromatin takes place, practically no development of a central spindle; but whether these two facts are related somehow as cause and effect must await further investigation. Hence we may regard the intranuclear figure in the case of Empusa and Coccidium, as an extremely simple apparatus, which consists merely of the two opposed centers of division, each with its system of polar radiations. Further, these polar rays must all correspond in function to the mantle-fibers, instead of in part to the extranuclear polar asters of the higher animals, since they all mark the paths of movement of chromatin material. As seen in *figs. 50, 54, 55, 59*, for example, the fact is quite apparent that the intranuculear centrosomes lie some distance from the nuclear membrane, and that there is no appreciable differentiation in the radiations which extend in all directions from them. All appear alike to consist, at least in part, of chromatin material. In later stages, represented in *figs. 64, 65*, the centers appear to have been pulled to the periphery so that they come to lie against the nuclear membrane. I am inclined to think that this peripheral position represents the ultimate fate of all of the centrosomes, since the very last stages (e. g., *fig. 61*) almost invariably show the old centers lying at one side against the nuclear membrane. Such figures lead us to believe that after all there may be a slight differentiation in the astral radiations, since those fibers which attach the centrosome to the nuclear membrane may be mainly concerned in this peripheral movement of the centers, forming in these instances a sort of "antipodal cone" of fibers. At any rate, while there may be, in such a spindle, certain polar structures which appear to have a special function and thus to form an "antipodal cone," there is no such striking differentiation of the aster into a "principal cone" and "polar rays" as was described by VAN BENEDEN.

In those more complicated centronuclei in which the chromatin is gathered during nuclear division into an equatorial plate and in which definite chromosomes are formed, as in Euglypha, Paramoecium, and

other Protozoa, a more or less clearly defined, fibrous, central spindle is found in addition to the mantle fibers. The absence of the central spindle in the simpler type of intranuclear division seen in Amoeba, Coccidium, and Empusa, and its meager development even in more complicated cases, clearly suggest that the central spindle-fibers, when present, play only a minor rôle in nuclear division as maintained by HERMANN ('91), viz., that they are non-contractile supporting elements, which form a basis on which the movements of the chromosomes take place. The chromatic structures in Empusa are undoubtedly moved poleward without the assistance of such connecting fibers, and they seem to be supported entirely by the surrounding nuclear sap.

These facts may be interpreted as thus furnishing a strong argument against the acceptance of the "pushing theory" of DRÜNER ('95), who supposes an active growth or elongation of the central spindle, thus pushing the spindle-poles farther and farther apart; and at least in part against the suggestion of MOTTIER (:03, :04), who thinks that the chromosomes may be conveyed to the poles both by a pushing and a pulling action of the spindle-fibers.

No clear explanation of the mechanism which accomplishes these primitive divisions has yet been marked out. As pointed out above, there are in Empusa no specially differentiated mantle-fibers, since the radiating astral rays of the intranuclear figure themselves mark the paths of the chromatin-movement. Whether the movements which take place in these radiations are similar to those which occur in the aster of the more highly differentiated extranuclear centrosphere, I cannot say, but this seems quite probable. In Empusa the radiations extend in all directions from the centrosome and some are anchored firmly to to the persistent nuclear membrane at its nearest point, while others project into the nuclear cavity, apparently ending free in the karyolymph. Now, a contraction of the radiating fibers would undoubtedly accomplish just the phenomenon which we see takes place. The fibers seem to shorten and to thicken, and an appearance suggesting an accumulation of darker staining material immediately around the centrosome results. The distal indentation of the nuclear membrane which we see occasionally (*figs. 64, 65*) should also be regarded as strong evidence that a pull of some sort or a contraction

of fibers in this region has taken place. But I can see no evidence in this instance of a using up of any of the material which has accumulated about the poles, as has been suggested by STRASBURGER (:00) to explain the shortening of the mantle-fibers in certain cases.

It may be pointed out in this connection that the fact that the fibrillar radiations in Empusa appear to be almost homogenous, and further, chromatic in their staining reactions instead of achromatic, does not seriously detract from the reasonableness of the contractile hypothesis, as applied to this form, since it is only necessary to assume that contractile linin is also present in small amount in the fibers, along with chromatin. WILSON ('95), in fact, maintains that in the case of echinoderm eggs, the fibers are derived not merely from the linin-substance, but also from the chromatin.

As in the telophases of mitotic processes in general, in the later stages in Empusa a centrifugal movement of the chromatin sets in, which may sometimes begin even before the two daughter-nuclei are separated by constriction from each other. *Fig. 59* shows such a late condition, in which the chromatin-movement seems to be of the nature of an active outward growth, since we now note at the distal ends of the fibers accumulations of darker and apparently denser material. Should we assume that the aggregation of chromatin about the centrosome in the first instance is brought about by the contractility of the kinoplasm in the radiations, then we must suppose that later some subtle change occurs in the body of the centrosome itself, or else in the fibrillar rays, to stop contraction and to set up an opposite growth of the fibers. But I should regard it as not an impossible assumption that the centrifugal movement in the latter instance might be brought about simply by a loosening up the chromatin in the increasing nuclear sap by which it is surrounded—a phenomenon which would probably follow as a mere mechanical consequence the final cessation of the forces which caused the centripetal movement.

The suggestion that these alternating centripetal and centrifugal movements of the chromatin are of the nature of flowing movements appears to gain some support in the case of Empusa. MONTGOMERY (:01, p. 352) concludes that this flowing movement of the nuclear materials is automatic; but I fail to see how this author can retain,

even in part as he does, the idea of the contractility of the secondary linin-fibrils, in addition to the above theory, since an automatic movement such as he conceives to take place should be regarded as an amoeboid movement in response to chemotropic stimuli. WILSON (:01, p. 575) also regards the chromatin as "a liquid substance which may be absorbed or given off by an achromatic basis such as plastin or linin, and may thus flow from one part of the nucleus to the other." The latter author appears to adopt to a certain extent the ideas of BÜTSCHLI ('92), in that in his studies on Toxopneustes he has become thoroughly convinced that the astral radiations are in part the result of centripetal currents, or diffusion-currents, of hyaloplasm converging on the centrosphere.

While it is quite possible that the chromatin in Empusa is a liquid substance which may flow or diffuse about through an achromatic linin basis, as WILSON suggests, this, in my opinion, does not preclude the idea of a contractile linin substance serving as the mechanism of mitotic division. I must say, however, that while entirely convincing evidence is lacking that the primitive mitosis in Empusa is accomplished by means of a contraction and a growth of the fibrillar, kinoplasmic radiations, there is, on the other hand, even less evidence in favor of other theories; for example, that the movement of the chromatin is automatic, due to chemotropic forces which are supposed to emanate from the centers; or that this movement is due to diffusion-currents induced by the chemism active at the centers; or that it results from magnetic or electrostatic forces, an idea which has been recently revived by LILLIE (:05).

In the primitive mitotic division characteristic of Empusa, we see but little resemblance to the corresponding process as described for other low plants. In all these cases, even in the Myxomycetes (HARPER, :00), a well-defined spindle and chromosome, and an equatorial arrangement of the chromatin may be observed. It is apparently very common among the thallophytes that the nuclear cavity and membrane persist during a large part of the mitotic processes; see, for example, figures of Erysiphe (HARPER, '97), of Albugo (STEVENS, :01), of Dictyota (MOTTIER, :00). But in all of those thallophytes in which centrosomes occur, the latter are *extra-* and not *intra*-nuclear bodies. Empusa is therefore in this respect unique

among the thallophytes and may be regarded as a primitive form; and further, the fact that it possesses intranuclear centers of division may perhaps be regarded as adding another point in favor of HERTWIG's ('98) view as to the intranuclear origin (by the extrusion of centrosome) forming substances from the nucleus of the extranuclear centrosomes of the more highly differentiated organisms.

It has been already pointed out above that Basidiobolus, which has been generally regarded as a member of the Entomophthoreae, shows in its mitotic features (its broad, multipolar spindles, and its formation, according to FAIRCHILD ('97), of a cell-plate), as well as in other morphological aspects, wide differences from Empusa.

Cell-division by means of the growth inward of a ring-formed wall is apparently a common type of division among the filamentous thallophytes. Such a constriction of the cell has so far been shown for Beggiatoa (HINZE, :01), the blue-green algae, Ulothrix (DIPPEL '65), Spirogyra (STRASBURGER,'80), Cladophora (DAVIS,'04), the red algae, and a few other forms. WOYCICKI (:04), contrary to FAIRCHILD'S ('97) assertions, contends that the cell-wall in Basidiobolus also is a centripetal growth. The gametes of Sporodinia and the conidia of Erysiphe are cut off in a similar manner, except that, according to HARPER ('99), the ingrowth here is simply a deep narrow furrow and not the growth inward of a ring of fungus cellulose. The wall in this case is deposited later between the two plasma-membranes.

As has been shown in this study of Empusa, the ring-formed cleavage-furrow starts at a definite region of the plasma-membrane, sometimes remote from the nuclei; and further, the nuclei at no time appear to be concerned, directly, in the process. TOWNSEND'S ('97) observations on nucleated and enucleated fragments of protoplasm leave no doubt, however, as to the ultimate necessity of the presence of a nucleus, in order to initiate the cytoplasmic activities in Empusa which lead to cell-division. Whether the localized stimulus in this case results first in a deposit of a ring of cellulose-substance on the inner surface of the wall of the mother-cell, which might then by its growth progressively inward be regarded as the agent of cleavage; or whether there first occurs in this region an infolding of the plasma-membrane, thus resulting in a circular furrow, to be soon followed by a deposit of wall-substance in the cleft, I am not able to state. In either

case, at any rate, the importance of the plasma-membrane as a factor in such a cell-division should be emphasized. The process in Empusa, in fact, would seem to furnish an argument in favor of NOLL's (:03) view that in Bryopsis the controlling factor of embryonic growth is located in the *Hautschicht*. Apparently in Empusa a definite region of the plasma-membrane is stimulated to action, a ring-formed infolding of the membrane occurs, and at once in the cleft thus produced, the new wall begins to be deposited. A darker accumulation, presumably of kinoplasm, may now be seen at the inner margin of the cleft (*figs. 18, 20*), where the activities leading to the cleavage of the inpushing plasma-membrane and to the ingrowth of the partition-wall are evidently greatest. But the plasma-membrane does not alone seem to be the active agent for these phenomena, for *fig. 18* shows a darker portion, having appreciable thickness, which apparently marks a more or less broad region of concentration of kinoplasm. This fact, therefore, may be regarded as an argument against the plasma-membrane itself being the sole controlling factor in this case. Further, MOTTIER'S ('99) experiments on Spirogyra and Cladophora, in which, by reason of the disturbance due to centrifugal force, the cellulose-ring, when once begun, was never brought to completion, notwithstanding the fact that the plasma-membrane was still intact, furnishes very convincing evidence against the acceptance of the theory that the *Hautschicht* alone is the controlling factor of wall-formation in these instances.

The fact that the cleft and ring-formed wall are finally carried across a wide vacuolar space (*figs. 17–21*), will not permit of the application to this case of SWINGLE'S (:03) explanation for the mechanism of the cleavage in Rhizopus, Phycomyces, and other forms. For it seems impossible to conceive how local contractions of the cytoplasm could cause the constriction of the cell in the case of Empusa. We could perhaps think of such a contraction as initiating the process, but that these forces could obtain after the narrow diaphragm of cytoplasm had begun to be pushed across the central vacuole, seems to me inconceivable.

In certain instances in Empusa, as, for example, when a germ-tube is formed (*figs. 8, 9*), the end cell of a filament keeps cutting itself off from behind, thus enabling the body of the protoplasm to

travel forward, so to speak, and to seek a favorable environment in which to grow. BREFELD ('83) seems to think, in the case of the similar phenomenon in Ustilago, that the cells which are thus cut off behind are empty, and that in this way no protoplasm at all is wasted in the process. If this were true, a cell-wall would be formed from a single plasma-membrane, thus differing from the division described above, in which the membrane is split so that the wall is deposited between the two. But the apparently empty cell retains its turgescence for a time before collapsing, thus proving that there is at least a film of protoplasm present. Further, sections of similar conditions in which conidia are cut off from a basal shooting-cell (*figs. 28, 36, 38*), show clearly the thin primordial sheath of enucleate protoplasm in the lower cell. The fact that the protoplasm of these lower cells seems to undergo speedy degeneration contributes another point in favor of the idea of the vital importance of the nucleus in nutrition.

I am at a loss to understand why the conidium should be regarded by THAXTER ('88, p. 143) as a one-spored sporangium, since in all the sections of conidia which I have examined there is no sign of a second inner wall. It may be that the plasma-membrane of the plasmolyzed contents of a conidium may have been mistaken for a wall; or, again, it is possible that this author's *figs. 320, 321* represent conidia still surrounded by the slimy protoplasm which is sometimes discharged from the ruptured basal cell.

I wish in conclusion to express my hearty thanks to Professor R. A. HARPER for the privileges afforded in his laboratories; to Professor W. S. MARSHALL, for assistance in the determination of insects; and to the Carnegie Institution of Washington, for a research assistancy under which this work has been done.

SUMMARY.

1. *Life history.*—The life history of *Empusa sciarae* may be summarized as follows: The disease attacks both larvae and adults of the host, Sciara, causing ultimately their death. The young, uninucleate germ-tubes, after they have entered the body-cavity of the insect, grow there at the expense of the nutrient fluids. After the protoplasm has increased in amount, a branching, coenocytic myce-

lium is produced, which in early stages is few septate; later, however, at the culmination of vegetative activity, septa are abundant and branching becomes more frequent.

Finally, the body-cavity becomes almost completely filled with the mycelial filaments, vegetative activity ceases and the death of the insect ensues with the beginning of the fructifying condition.

Radial branches, which mark the beginnings of the conidiophores, are put forth from the short, 3–5-nucleate cells which make up the mature mycelium; in this species, but one branch grows from each cell. These radial hyphae bore their way out through the body-wall of the insect; some form the rhizoids which attach the host to the substratum, while others grow into branched conidiophores. Each conidiophore is cut up by cell-division into uninuclueate segments, each of which pushes out beyond the surface of the host and cuts off from its tip a single uninucleate conidium. The basal cell below the conidium comes to possess but a thin, enucleate primordial utricle, and it finally becomes greatly swollen from the absorption of water. Ultimately this swollen basal vesicle bursts in a ring at the top where it joins the conidial wall, or the columella-like wall may be split in some instances, and the conidium is thus shot violently away, the slimy protoplasmic contents of the lower cell being frequently carried along with the conidium and serving to stick the latter to the substratum. The partition which cuts off the conidium is at first curved upward by the greater turgescence of the vesicle; but when the spore is shot off, this reverses its former position, and in the conidium it appears as a prominent papilla.

2. *Nuclear division.*—The nuclei of Empusa are "centronuclei," since the centrosomes which are active during division are permanently intranuclear.

The division of the nuclei which takes place during the vegetative stages appears to be of the nature of a primitive mitosis, similar in many respects to that described for certain of the simpler Protozoa. The nuclear membrane generally persists during the whole process. A simple intranuclear figure is formed, which in later stages consists of the two opposed centers of division, to each of which converges from all sides a system of fibrous radiations. The many radiations which converge at the two poles correspond to the chromosomes; and,

although they appear to be chromatic in their staining reactions, they probably are made up principally of chromatin, and a small amount of linin. The chromatin at first concentrates about the centrosomes, which thus appear to have a darker rim about a lighter center. The centripetal movement, as well as the later centrifugal movement characteristic of the telophases, may be regarded as of the nature of the flowing or diffusion of a liquid chromatin through a contractile linin basis.

In the nuclear division of *Empusa sciarae*, the chromatin does not appear to pass through an equatorial plate stage.

We may distinguish two shapes of the dividing nuclei in Empusa: one found in short cells of the vegetative hyphae, in which the nuclei in the later stages of division assume an oval or ellipsoidal shape; and another found in long cells, in which the nuclei become themselves greatly elongated and early assume a constricted, hour-glass shape. In the oval nuclei, the nuclear sap accumulates so that the cavity becomes turgescent; while in the elongated nuclei, the liquid does not accumulate, at least not to such an extent as in the first instance, so that the consequent encroachment of the cytoplasm between the two daughter-halves results in an early constriction. In the long cells, cyclosis is doubtless stronger than in the short cells, thus bringing about in such instances a greater disturbance of the mitotic processes.

3. *Cell-division.*—Cell-division in *Empusa sciarae* is accomplished by means of the growth inward, from the wall of the mother-cell, of a ring-formed partition. In a majority of cases, the new cell-wall is carried across a wide, central, vacuolar space; when the older cells become filled with cytoplasm, however, and later when the conidium is abstricted, the wall cuts through the protoplasm which fills the cell. A ring-formed cleavage-furrow starts at a definite region of the plasma-membrane, and a wall is at once deposited in the cleft. A region of some thickness at the inner margin of the cleft, where the processes are most active which lead to the cleavage of the in-pushing plasma-membrane and to the deposition of the partition wall, stains darker than the surrounding cytoplasm. This fact is made the basis for the conclusion that the split plasma-membrane is not the sole active agent of cell-division, although it may be

a controlling factor in the process. Cell division, in this instance, is regarded as a cytoplasmic phenomenon, since the nuclei may be remote from the place of constriction; and, further, they appear to have nothing directly to do with the process. The ultimate necessity of the presence of a nucleus, probably as a controlling factor of nutrition, is proven, however, by the early death of the enucleate basal cells cut off from the conidia and from the end-cells of germ-tubes.

UNIVERSITY OF WISCONSIN,
Madison.

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EXPLANATION OF PLATE XVI.

The drawings were made with the aid of an Abbe camera lucida, together with the Zeiss 2 mm apochromatic obj. N. A. 1:30, combined with compensating ocular 12; except *fig. 16*, which was drawn with compensating ocular 18.

FIGS. 49–65, *Empusa sciarae*. All ×1500, except fig. 64, which is ×2250.

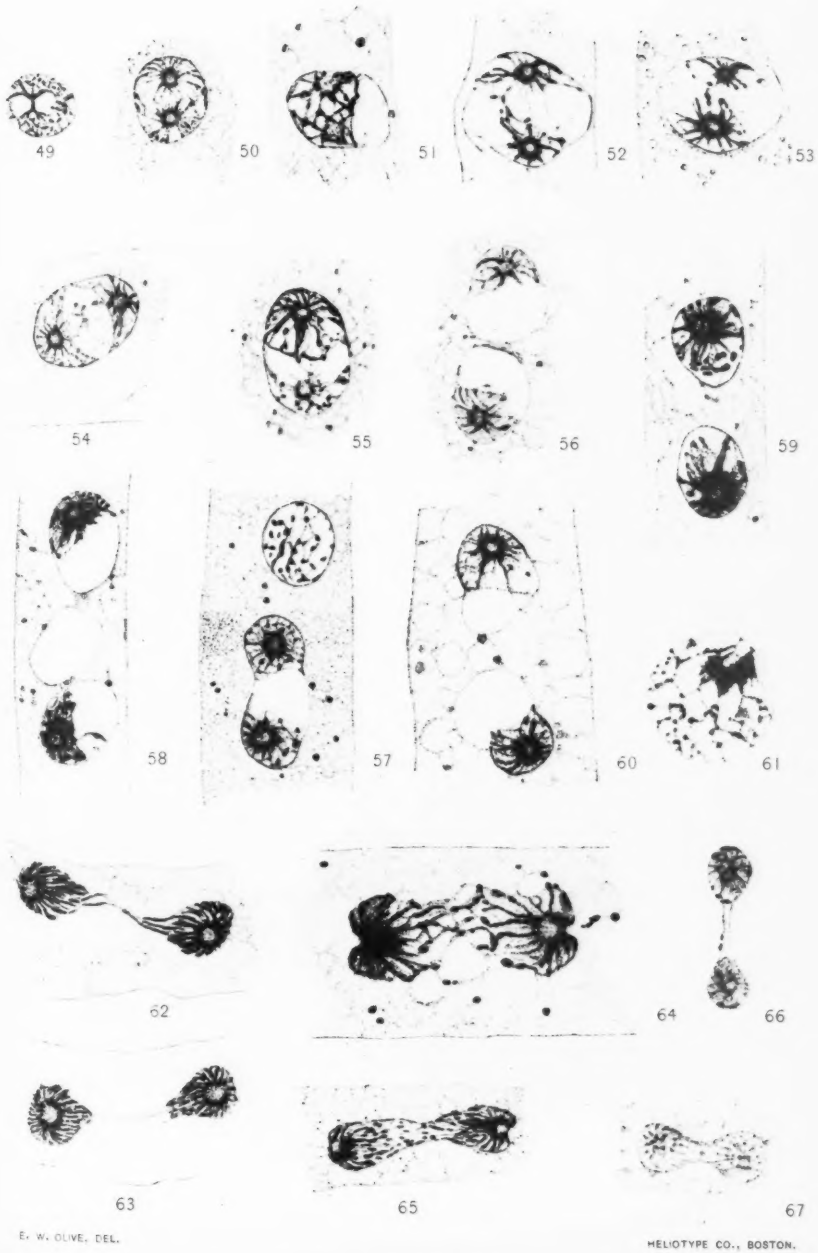
FIG. 49. Probably an early prophase of division.

FIG. 50. A considerably advanced stage of division.

FIG. 51. A poorly differentiated preparation in which the karyolymph has accumulated at one side of the dividing nucleus.

FIG. 52. A thin section of an anaphase.

FIG. 53. A similar preparation.



E. W. OLIVE, DEL. HELIOTYPE CO., BOSTON.

OLIVE on EMPUSA.

FIG. 54. A stage in which the daughter-halves appear to be pressed upon by the turgescent, vacuolar middle portion.

FIG. 55. A partly polar view of an obliquely placed nucleus, showing about 16 fibrillar radiations extending from the centrosomes.

FIG. 56. A late condition in which the daughter-nuclei have just been separated from each other by a cytoplasmic constriction. The nuclear contents occupy a pseudo-synaptic position.

FIG. 57. Showing in the upper portion of the hypha a resting nucleus and in the lower, a late stage of nuclear division.

FIG. 58. A double cytoplasmic constriction has taken place so that a vacuole filled with nuclear sap is left between the two daughter-nuclei.

FIG. 59. A telophase condition.

FIG. 60. Another telophase condition.

FIG. 61. Probably a very late telophase, in which the dark rim of the center has survived, whereas the achromatic centrosome-portion has disappeared.

FIG. 62. A late condition of nuclear division which is characteristic of elongated cells.

FIG. 63. A somewhat later stage, also from an elongated cell.

FIG. 64. A younger stage, in which the nuclear membrane has been indented at the ends of the nucleus distally from the poles.

FIG. 65. An elongated nucleus in division, in which one pole shows an indentation.

FIGS. 66, 67, *Empusa aphidis*. ×1500.

FIG. 66. A poorly stained preparation, showing the division characteristic of the elongated cells of this species.

FIG. 67. An earlier stage of division.

BIOLOGICAL RELATIONS OF DESERT SHRUBS.

II. ABSORPTION OF WATER BY LEAVES.

V. M. SPALDING.

DURING a study of certain shrubs growing in the vicinity of the Desert Botanical Laboratory near Tucson, Arizona, it has been found that the leaves of some of them absorb water, while those of others do not. Although leaf absorption is treated by leading physiologists as a matter of indifference, or at any rate of secondary importance, it has seemed worth while to inquire whether differences of habit in this particular, on the part of these desert plants, may not be correlated with other characteristic peculiarities; if so, even if the fact should turn out to be of small importance physiologically, it may be significant from a biological point of view.

Our knowledge of leaf absorption as yet is fragmentary and uncertain. For the general subject it is quite unnecessary to cite the voluminous and contradictory literature. DANDENO[1] has given a useful historical résumé, reference to which and to paragraphs in BURGERSTEIN'S more recent work[2] is sufficient for the present purpose. In regard to various highly modified plants, however, the case is quite different. SCHIMPER has made such detailed observations of certain epiphytes as to leave no doubt that they normally absorb large quantities of water through their aerial parts, and that this is a distinct physiological advantage, or even necessity. In view also of investigations cited by BURGENSTEIN it becomes necessary to accept the fact of leaf absorption in the case of various other plants.

As for the plants of arid regions, the evidence has been less conclusive than could be wished. VOLKENS, in his classical work, describes various special structures by means of which, presumably, many of the plants of the Egyptian-Arabian desert take up dew

[1] DANDENO, J. B. An investigation into the effects of water and aqueous solutions of some of the common inorganic substances on foliage leaves. Trans. Can. Inst. 7:238. 1901.

[2] BURGERSTEIN, A., Die Transpiration der Pflanzen. 1904.

through their leaves, but the woody species growing in the arid territory of the southwestern United States are so different in their habits and in their environmental relations as to preclude the settlement of the question for them, even within the bounds of probability, in any other way than by direct observation and experiment; in fact they are found, as regards leaf absorption, to differ widely among themselves. The object of the present paper, therefore, is the presentation of such facts as have been determined for a limited number of species indigenous to southern Arizona.

In this region existing physical conditions give to the question special interest. As is well known, precipitation is meager, except at relatively high altitudes, and is distributed throughout the year, with no distinctively rainy season. The rainfall, moreover, is extremely uncertain, and for months at a time is often so slight that it does not wet the soil for more than a few centimeters, an amount of precipitation likely to be of very little positive advantage as far as root absorption is concerned. Under such circumstances, in which delicate adjustment is the condition of survival, it would seem that plants capable of leaf absorption might have a distinct advantage in times of prolonged drouth, during which occasional showers occur which are too light to penetrate the soil. As will be seen, however, only a limited number of species appear to enjoy this advantage to an appreciable extent.

Nearly all of the species selected for investigation grow in the immediate vicinity of the Desert Laboratory. A single one, *Holacantha Emoryi*, which seems not to be indigenous here, was obtained from the grounds of the University of Arizona. The following classification of the plants employed into biological groups is provisional, but will serve to direct attention to the very diverse ecological history of the species now growing together in this region.

BIOLOGICAL CLASSIFICATION OF PLANTS STUDIED.

I. Shrubs, with relatively slight modification of form and structure, their habits plainly indicating mesophytic origin. Celtis, Covillea, Lycium.

II. Shrubs or small trees, more conspicuously modified, but retaining manifest traces of mesophytic habits. Parkinsonia, Prosopis, Acacia.

III. Woody or partly herbaceous plants, exhibiting peculiar modifications of distinctly xerophytic types. Fouquieria, Holacantha, Koerberlinia, Zizyphus, Atriplex.

IV. Plants of the most pronounced xerophytic character. Opuntia, Cereus, and other cacti.

V. Plants adapted by habit, rather than structure, to desert conditions. Sphaeralcea and many other half-shrubby or more or less herbaceous forms.

Of the species employed in the experiments, *Celtis pallida* is a shrub, growing commonly to the height of one to one and one-half meters on the laboratory hill, where it is rather abundant. It holds its foliage so well that it might be ranked as an evergreen, though it suffers to some extent from the effects of frost. Its leaves are rough-hairy, thin but firm in texture, and conforming in general to the generic type. *Covillea tridentata*, the well-known creosote bush, is the most abundant woody species of this region. Its small coriaceous leaves, presented more or less edgewise to the sun and covered with waxy varnish, are well protected against excessive transpiration. *Lycium Berlandieri* is a small shrub, more than a meter in height, of frequent occurrence on rocky exposures. These species, of the three genera named, while well adapted to their habitat, exhibit characters far less conspicuously xerophytic than those of many of the plants with which they are associated.

Coming to the second group, *Parkinsonia Torreyana* attains the dimensions of a small tree, and is conspicuous by reason of its green bark, from which it has the common name of *palo verde*. Though a denizen of the desert, it is not a dry ground form, but frequents low places, where more water is available than on the mesa or even on the adobe soil of the hills, where *Parkinsonia microphylla*, a related species, does well. *Prosopis velutina*, the mesquite, grows chiefly in low ground, within reach of abundant water, but it also occurs, though scattering and undersized, on the adobe soil of rocky hills. Like the *palo verde* and many other leguminous plants, the leaves of the mesquite exhibit in their structure and position excellent adaptations for the prevention of excessive transpiration. *Acacia constricta*, of similar distribution, occurs on the mesa and also on rocky upland. It is a vigorous shrub,

one or two meters in height. These several species of Parkinsonia, Prosopis, and Acacia thrive well under the rather severe conditions to which they have become accustomed; they all retain, however, manifest traces of mesophytic habits, particularly in their choice of habitat.

The species assigned to the third group, among which are *Fouquieria splendens*, *Holacantha Emoryi*, *Koerberlinia spinosa*, and *Zizyphus lycioides*, present more striking modifications of form and structure than do any of the members of the preceding groups, and, though differing greatly among themselves, agree in possessing such conspicuous adaptations to xerophytic conditions as easily to rank next to members of the following biological group.

The cacti are commonly taken to represent the extreme type of xerophytes, but notwithstanding various striking features common to members of this order, there are essential differences of habit and adaptation, even between closely related species, rendering it quite impossible to generalize from the study of "typical forms" in the investigation of biological problems presented by them.

The half-shrubby and herbaceous plants are much like those of other regions, exhibiting as a rule no structures that would be thought of as distinctively xerophytic, but accommodating themselves to desert conditions by their habits, especially such as enable them to take advantage of periods favorable for rapid development and production of seeds.

By way of first ascertaining whether any of the plants of these several groups absorb enough water through their leaves or internodes to be readily detected by weighing, the following method was employed: A small branch with leaves functionally active, though often showing plainly the effects of long drouth, was severed and the cut end immediately covered with vaseline. In a few instances, which are specified, branches without leaves were used. The branch was then weighed and directly afterwards immersed in water, except at the cut end, for a definite time, usually about three hours. At the end of this period, after exposure to the open air long enough to be certain that the surface was fully dry, the branch was again weighed, and the increase of weight, if any, was

taken to represent closely the amount of water absorbed, though, owing to loss during the operation of drying the surface, the amount absorbed must often have been rather greater than the increase of weight indicated. In the first preliminary set of observations, a pair of large balances, weighing satisfactorily to ten milligrams, was employed; but in subsequent experiments quantitative balances were used, the weighing being made to a milligram in each case. Changes during the process of weighing rendered it as useless as it was unnecessary to attempt a higher degree of accuracy.

Inspection of Table I shows that leafy shoots of Celtis, Covillea, and Lycium, by immersion in water for three hours, gained 1.9 to 5 per cent. of their original weight; Atriplex in a little longer

TABLE I.

PRELIMINARY TEST OF CAPACITY FOR ABSORPTION. *November 1904.*

Species	Date	Time	Weight in grams	Gain or loss per cent.
Covillea tridentata (1).....	Nov. 1	10:12 A. M.	18.540	
		1:12 P. M.	19.250	3.8 gain
Covillea tridentata (2)	" 9	10:55 A. M.	8.235	
		1:56 P. M.	8.650	5.0 "
Celtis pallida.....	" 1	10:57 A. M.	24.920	
		1:57 P. M.	26.000	4.3 "
Lycium Berlandieri.....	" 1	10:45 A. M.	7.105	
		1:45 P. M.	7.240	1.9 "
Acacia constricta.....	" 1	11:14 A. M.	6.260	
		1:14 P. M.	6.352	1.5 "
Prosopis velutina.....	" 1	10:30 A. M.	4.200	
		1:30 P. M.	4.250	1.2 "
Parkinsonia microphylla.....	" 1	10:22 A. M.	10.410	
		1:22 P. M.	10.490	0.8 "
Parkinsonia Torreyana.....	" 9	11:03 A. M.	4.070	
		2:02 P. M.	4.085	0.4 "
Atriplex canescens.....	" 17	10:21 A. M.	2.140	
		1:44 P. M.	2.250	5.1 "
Zizyphus lycioides.....	" 9	11:39 A. M.	19.270	
		3:25 P. M.	19.320	0.3 "
Fouquieria splendens.....	" 9	11:21 A. M.	21.770	
		2:24 P. M.	21.920	0.7 "
		3:32 P. M.	21.770	
Koerberlinia spinosa.....	" 10	10:41 A. M.	8.650	
		1:40 P. M.	8.670	0.2 "
Encelia farinosa.....	" 9	12:00 M.	5.010	
		3:00 P. M.	5.320	6.2 "
		3:18 P. M.	5.000	
Sphaeralcea pedata.....	" 9	12:07 P. M.	1.120	
		3:12 P. M.	1.180	5.4 "
		3.21 P. M.	1.110	

period gained 5.1 per cent.; Parkinsonia, Prosopis, and Acacia gained 0.4 to 1.5 per cent.; and Zizyphus, Fouquieria, and Koerberlinia, all without leaves, showed almost no appreciable gain. Species of Sphaeralcea and Encelia gained in weight 5.4 and 6.2 per cent. respectively, but promptly lost all they had gained by a few minutes drying.

It will be noticed that of the plants employed in this preliminary work those without leaves absorbed no water to speak of, while those in leaf fell into two categories, those absorbing and those not absorbing water in quantity. The experiment, therefore, pointed to leaves rather than internodes as agents of absorption, and indicated, apart from Sphaeralcea, Encelia, and the peculiar Atriplex, only the woody species belonging to the first group as likely to prove capable of absorbing much water.

Starting with the suggestions derived from these facts, a more careful and detailed study was undertaken. Cut shoots were still employed for a time, though it was understood that confirmation of results would necessitate the use of entire plants, and these were, as a matter of fact, employed to a large extent in the later work. Care was exercised in the selection of material, and in each case its source and any conditions liable to affect results were noted.

GROUP I.

Celtis pallida.

Four specimens of this species were selected, all in good condition, though apparently not as active physiologically as they would have been earlier in the year. Numbers 1 and 2 were fresh shoots, while numbers 3 and 4 were small branches taken from older bushes. Those numbered 1 and 3 were cut so as to include a large leaf surface as compared with the other two. In every case the cut ends were covered at once with vaseline, and the first weighing was made as soon as practicable after bringing them to the laboratory. They were then wet at frequent intervals for a little more than three hours, and, after drying the surface, were weighed again, after which they were left in the laboratory to dry until the next day, when the same steps were repeated. Finally they were immersed in water over night and again weighed.

TABLE II.

CELTIS PALLIDA. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Period of treatment
1	Dec. 19	10:44 A. M.	1.834		
		1:55 P. M.	1.853	1 gain	After wetting nearly 3 hrs. 11 min.
	20	9:48 A. M.	1.516	18.2 loss	" drying 19 hrs. 53 min.
		2:10 P. M.	1.592	5 gain	" wetting nearly 4 hrs. 22 min.
	21	10:35 A. M.	1.895	19 "	" " " 20 " 25 "
2	19	10:54 A. M.	1.392		
		2:02 P. M.	1.410	1.3 gain	After wetting nearly 3 hrs. 8 min.
	20	9:57 A. M.	1.192	15.5 loss	" drying 19 hrs. 55 min.
		2:25 P. M.	1.238	3.9 gain	" wetting nearly 4 hrs. 28 min.
	21	10:52 A. M.	1.440	16.3 gain	" " " 20 " 27 "
3	19	11:13 A. M.	2.137		
		2:20 P. M.	2.185	2.2 gain	After wetting nearly 3 hrs. 7 min.
	20	10:07 A. M.	1.734	20.6 loss	" drying 19 hrs. 47 min.
		2:38 P. M.	1.870	7.8 gain	" wetting nearly 4 hrs. 31 min.
	21	11:05 A. M.	2.182	16.7 "	" " " 20 " 7 "
4	19	11:25 A. M.	1.505		
		2:31 P. M.	1.521	1.1 gain	After wetting nearly 3 hrs. 6 min.
	20	10:16 A. M.	1.351	11.2 loss	" drying 19 hrs. 45 min.
		2:46 P. M.	1.387	2.7 gain	" wetting nearly 4 hrs. 30 min.
	21	11:15 A. M.	1.535	10.7 "	" " " 20 " 29 "

Inspection of Table II shows:

1. That all four specimens absorbed water very slowly just after they were freshly cut, and that the rate of absorption was greatly increased after they had lost weight by remaining over night in the dry air of the laboratory.

2. The rate of absorption showed a correlation with extent of leaf surface, being considerably greater in the two specimens with large extent of leaf surface than in the other two.

3. The weight lost by drying for a given period was nearly or quite regained when the leaves were given a full supply of water for a corresponding length of time. The capacity of this species for leaf absorption, under the conditions described, is thus fully demonstrated. Its deportment in the seedling stage, which offered for experiment perfectly fresh and unmutilated material, will next be considered.

Seedlings of *Celtis pallida* were grown from seeds sown November 14, 1904. When used for experiment in January and February,

1905, they were all in healthy condition, and when taken up were found to have fine vigorous roots. In addition to the cotyledons, which were still capable of photosynthesis, each seedling had two or three perfectly healthy green leaves that had attained the length of about one centimeter. The seedlings were transplanted into earth contained in glass vials of convenient size for accurate weighing, sheet rubber being used to prevent evaporation from the soil.

In the case of seedling number 1 the earth was very moist when the rubber was adjusted, and it was found that this plant, which was transpiring vigorously, showed almost no capacity for absorption. The case was different with seedling number 2, which was left some five days after transplanting with the soil open to the air, so that it became relatively dry before the rubber was adjusted. The cotyledons of number 1 were removed, their place of attachment being carefully covered with vaseline; number 2 had one large cotyledon which remained in place during the experiment. These details are necessary to an understanding of the different behavior of the two seedlings as shown by Tables III and IV, which cover the period from January 21 to February 1, at which latter date the experiment was concluded.

It is seen that both seedlings transpired regularly and largely, but that number 1, in spite of the fact that its transpiring surface had been lessened by the loss of its cotyledons, exhibited a decidedly higher rate of transpiration than number 2, which was in drier

TABLE III.

CELTIS PALLIDA. SEEDLING NO. 1. *January 1905.*

Date	Time	Weight in grams	Loss or gain	Conditions
Jan. 21	1:19 P. M.	26.256		
	4:05	26.229	0.027 loss	After standing in dry air
23	10:15 A. M.	26.094	0.135 "	" " " " "
	2:50 P. M.	26.061	0.033 "	" " " " "
25	10:50 A. M.	25.936	0.125 "	" " " " "
26	9.50	25.870	0.066 "	" " " " "
27	9:28	25.806	0.064 "	" " " " "
	2:53 P. M.	25.810	0.004 gain	After wetting
	3:41	25.803	0.007 loss	" standing in dry air
28	11:02 A. M.	25.762	0.041 "	" " " " "
	1:33 P. M.	25.764	0.002 gain	" wetting
	2:58	25.759	0.005 loss	" standing in dry air

TABLE IV.

CELTIS PALLIDA. SEEDLING NO. 2. *January and February 1905.*

Date	Time	Weight in grams	Loss or gain	Conditions
Jan. 30	10:09 A. M.	22.638		
	1:10 P. M.	22.630	0.008 loss	After standing in dry air
	3:40	22.626	0.004 "	" " " " "
31	9:45 A. M.	22.653	0.027 gain	" wetting
	12:45 P. M.	22.628	0.025 loss	" standing in dry air
	3:13	22.634	0.006 gain	" wetting
Feb. 1	9:48 A. M.	22.592	0.042 loss	" standing in dry air
	9:50	0.027		Weight of plant above ground
	2:08 P. M.	0.045	0.028 gain	After wetting

soil, an interesting result in harmony with earlier experiments, showing the direct relation between available soil water and rate of transpiration.[3]

On the other hand, while the quantity of water absorbed by number 1 was so meager as to be negligible, that absorbed by number 2 was much more, in one case almost exactly 100 per cent. of its own weight, i. e., of the part above ground when it was afterwards severed from the root. Number 2, although apparently perfectly healthy while the work was in progress, seems nevertheless to have reached a condition in which the diminished supply of water from the soil was followed by a marked acceleration of leaf absorption, while in the case of number 1, growing as it was in moist soil, no such compensation was made or required.

Of interest as bearing on the validity of determinations of absorption by the use of detached shoots is the fact that while seedling number 2, after it had finally been cut off at the surface of the ground, absorbed in a few hours its own weight of water, it had done precisely the same thing before mutilation, only in longer time. It may well be that a detached shoot, cut off from its normal source of water supply, will absorb more rapidly through its leaves than the same shoot, which, while attached, is supplied, even inadequately, from the soil; but this difference plainly does not justify the degree of discredit that has been thrown upon evidence derived from experiments with separated parts of plants.

Three other seedlings of *Celtis pallida* were treated like the preceding ones, except that the observations were not begun until

3 SPALDING, V. M., Soil water in relation to transpiration. Torreya **5**:25. 1905.

the plants had been some weeks in the vials to which they were transplanted, and weighings were made during a longer period and with more complete records as to soil conditions, health of seedling, etc. Their records as to weight are given in Tables V, VI, and VII. All of these seedlings were in a healthy condition and apparently capable of entirely normal development. The small extent of surface through which absorption and transpiration took place renders the consistency of the results all the more striking. In every case water was absorbed when it was presented to the leaves and internodes, and transpiration was resumed as soon as their surfaces were dried.

TABLE V.

CELTIS PALLIDA. SEEDLING NO. 3. *February 1905.*

Date	Time	Weight in grams	Loss or gain	Conditions
Feb. 14	11:20 A. M.	23.084		Weight of seedling and outfit
	2:25 P. M.	23.091	0.007 gain	After immersion in rain water
15	9:40 A. M.	23.044	0.047 loss	" standing in dry air
	11:55	23.053	0.009 gain	" immersion in rain water
16	11:42 A. M.	23.007	0.046 loss	" standing in dry air
17	2:11 P. M.	23.046	0.039 gain	" immersion in rain water
20	10:23 A. M.	22.895	0.151 loss	" standing in dry air
	2:51 P. M.	22.916	0.021 gain	" immersion in rain water
21	10:28 A. M.	22.932	0.016 "	" " " " "
	12:00 M.	22.907	0.025 loss	" standing in dry air
	3:02 P. M.	22.887	0.020 "	" " " " "
22	12:08	22.835	0.052 "	" " " " "
	12:11	22.828		Weight after removing cotyledon
	2:14	22.835	0.007 gain	After immersing in rain water
	2:34	0.035		Weight when cut at surface of earth
	2:38	22.799		" of vial, rubber, and earth
25	1:58	0.015		" of plant above ground, air-dried in laboratory

When the first weighing was made, February 14, seedling no. 3 had two cotyledons, still attached, and three foliage leaves. The cotyledons showed some indications of drying. The earth in the glass vial in which the seedling was growing was becoming rather dry, but still contained sufficient water to maintain a transpiration current for a week and probably longer. On February 16, the note was made "one of the cotyledons drying, curled, and getting stiff; the other paler than the foliage leaves, but still flexible, otherwise the seedling is in good condition."

On February 22 the cotyledons were removed and the subse-

quent deportment of the seedling indicates that their failing condition previous to removal may be disregarded as not materially affecting the results. As the table shows, the weight of the whole plant above ground, including cotyledons, was less than the weight of water transpired in 19 hours (Feb. 14–15) and also less than the gain of weight by absorption in 26 hours (Feb. 16–17), a conclusive proof of the relatively large quantities of water absorbed and transpired by this seedling during the period of experimentation. The facts regarding seedlings 4 and 5 are so fully set forth in Tables VI and VII as to render further explanation unnecessary.

TABLE VI.

CELTIS PALLIDA. SEEDLING NO. 4. *February and March 1905.*

Date	Time	Weight in grams	Loss or gain	Conditions
Feb. [illegible]	[illegible] P. M.	20.130		Weight of plant and outfit
15	10:02 A. M.	20.090	0.040 loss	After standing in dry air
	12:47 P. M.	20.093	0.003 gain	" immersion in rain water
16	12:00 M.	20.031	0.062 loss	" standing in dry air
17	3:11 P. M.	20.051	0.020 gain	" immersion in rain water
20	10:46 A. M.	19.821	0.230 loss	" standing in dry air
	3:19 P. M.	19.825	0.004 gain	" immersion in rain water
21	10:54 A. M.	19.830	0.005 "	" " " " "
	12:11 P. M.	19.813	0.017 loss	" standing in dry air
22	12:29	19.696	0.117 "	" " " " "
	3:08	19.707	0.011 gain	" immersion in rain water
March 2	10:04 A. M	19.080	0.627 loss	" standing in dry air
	2:04 P. M.	19.085	0.005 gain	" immersion in rain water
	2:25	19.080	0.005 loss	" standing in dry air
	2:30	0.070		Weight when cut off at surface of earth

TABLE VII.

CELTIS PALLIDA. SEEDLING NO. 5. *February 1905.*

Date	Time	Weight in grams	Loss or gain	Conditions
Feb. 20	11:16 A. M.	20.207		Weight of plant and outfit
	3:28 P. M.	20.204	0.003 loss	After wetting with rain water (not immersing)
21	11:09 A. M.	20.219	0.015 gain	After immersion in rain water
	12:15 P. M.	20.214	0.005 loss	" standing in dry air
22	12:34	20.172	0.042 "	" " " " "
	3:18	20.178	0.006 gain	" immersion in rain water
	3:33	0.025		Weight when cut off at surface of earth
25	2:11	0.012		Weight after air drying

Covillea tridentata.

The specimens of creosote bush selected for experiment were taken from four different sources, for the sake of securing material as different as practicable in regard to the amount of water in the tissues. Number 1 was from a bush growing near an irrigating ditch, where it had been abundantly supplied with water. Its leaves were large, dark green, and fresh, and numerous flower buds had been formed. Number 2 was from a plant growing on the mesa a few rods distant. Its leaves were smaller and lighter green, and in comparison with number 1 it was plainly a dry ground form, though it did not have the appearance of having suffered to any great extent from lack of water. Numbers 3 and 4 were from plants growing on the mesa, near the foot of the laboratory hill, where in a dry time the Covillea, the only shrub that keeps alive there, shows the effects of drouth very badly. Their leaves were still smaller and paler in color, those of number 4 especially, indicating by their minute size and other peculiarities a plant that had long lacked a sufficient supply of water. The contrast between this and the first member of the series was very striking. It should be stated, however, that none of the specimens were in quite so dried-up a condition as those employed early in November before the December rains, which though meager—0.82 inch (21^{mm}) thus far—had freshened vegetation to some extent. The dried-up leaves that were dying in November had been shed, and the leaves remaining on the bushes when the experiment was conducted, late in December, were apparently in a vitally active condition.

It will be noticed by reference to Table VIII that, precisely as in the case of Celtis, all the specimens of Covillea gained very little in weight as the result of wetting soon after they were cut. Number 1, from the irrigated bush, gained least, and number 4, from the dry ground plant, gained most. After prolonged drying and again wetting, the gain was much greater than before, the greater gain in each case being made by number 4, which, as already stated, was from the most distinctively dry ground form.

The deportment of number 1, from the robust, well-watered bush, is instructive, especially as it may throw light on the question as to whether leaf absorption is a normal process that takes place

TABLE VIII.

COVILLEA TRIDENTATA. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Period of treatment
1	Dec. 26	11:05 A. M.	2.529		
		2:17 P. M.	2.538	0.4 gain	After wetting nearly 3 hrs. 12 min.
	28	10:32 A. M.	1.957	22.9 loss	" drying 44 hrs. 15 min.
		2:18 P. M.	1.996	2.0 gain	" wetting nearly 3 hrs. 46 min.
	29	10:50 A. M.	2.188	9.6 "	" " " 20 " 32 "
2	26	11:12 A. M.	2.434		
		2:35 P. M.	2.453	0.8 gain	After wetting nearly 3 hrs. 23 min.
	28	10:40 A. M.	2.234	8.9 loss	" drying 44 hrs. 05 min.
		2:33 P. M.	2.258	1.1 gain	" wetting nearly 3 hrs. 53 min.
	29	11:03 A. M.	2.416	7.0 "	" " " 20 " 30 "
3	26	11:21 A. M.	2.261		
		2:58 P. M.	2.281	0.8 gain	After wetting nearly 3 hrs. 37 min.
	28	10:48 A. M.	1.980	13.2 loss	" drying 43 hrs. 50 min.
		2:45 P. M.	2.020	2.0 gain	" wetting nearly 3 hrs. 57 min.
	29	11:14 A. M.	2.225	10.1 "	" " " 20 " 29 "
4	26	11:28 A. M.	2.646		
		3:03 P. M.	2.688	1.6 gain	After wetting nearly 3 hrs. 35 min.
	28	10:55 A. M.	2.357	12.3 loss	" drying 43 hrs. 52 min.
		2:56 P. M.	2.415	2.5 gain	" wetting nearly 4 hrs. 1 min.
	29	11:23 A. M.	2.766	14.5 "	" " " 20 " 27 "

under natural conditions. This shoot, with its large, fresh, turgid leaves, lost water by drying approximately twice as rapidly as did those from dry ground, with their much smaller leaves and firmer tissues, and on subsequent wetting absorbed far less than the latter in proportion to previous loss. Unlike these, moreover, the leaves of the first specimen, in the course of alternate drying and wetting, lost their fresh look and became discolored. The impression was received that this specimen, taken from a perfectly fresh plant and requiring no additional supply of water, suffered pathological changes in the course of the treatment to which it was subjected, while the others, coming from dry ground plants in need of water, absorbed it as by a perfectly normal process. Even these, however, were not in a condition for rapid leaf absorption when first cut, their gain per cent. being decidedly less for a given period than that exhibited by individuals of the same species during observations made before the December rains. In brief, the experiments of December 26–29, in connection with those of November 1–9, indicate on the part of the creosote bush marked capacity for

subaerial absorption after protracted drouth, but more limited capacity for such absorption, even if artificial drying is resorted to, when it is receiving a better supply of water.

Lycium Berlandieri.

At the time when the observations on Lycium were made, late in December, most of the summer leaves had fallen and fresh ones, following recent light rains, were only beginning to appear. Consequently it was difficult to secure entirely satisfactory material, but a few specimens were finally obtained for experiment which were in a normal and active condition. The leaves of this species are small, only about one centimeter in length, but otherwise the plant gives the impression, as already stated, of having retained up to the present time distinctively mesophytic tendencies. The rapidity with which the leaves were transpiring was at once obvious when weighing was undertaken, and, as in cases previously cited, absorption was found to take place extremely slowly while the leaves were still fresh. Even after drying, water was absorbed in no case as rapidly as it had been lost. Thus number 2 lost 3 per cent. of its weight by drying three and one-half hours, and gained afterwards by wetting nearly four hours 1.9 per cent. Of the actual capacity of this species for subaerial absorption the experiments leave no room for doubt; but the specimens employed deported themselves much like the well-watered Covillea, except that no suggestion of pathological change in the course of the treatment to which they were subjected was noted. When gathered they were simply in the condition of fresh, actively transpiring plants,

TABLE IX.

LYCIUM BERLANDIERI. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Period of treatment
1	Dec. 28	10:15 A. M.	3.065		
		1:47 P. M.	3.076	0.4 gain	After wetting nearly 3 hrs. 32 min.
	29	10:15 A. M.	3.235	5.2 "	" " nearly 20 hrs. 28 min.
		1:42 P. M.	2.956	8.7 loss	" drying 3 hrs. 27 min.
		3:25	3.002	1.6 gain	" wetting nearly 1 hr. 43 min.
2	28	10:22 A. M.	3.122		
		1:56 P. M.	3.028	3.0 loss	After drying 3 hrs. 34 min.
	29	10:00 A. M.	2.802	7.5 "	" " 20 " 04 "
		1:53 P. M.	2.855	1.9 gain	" wetting nearly 3 hrs. 53 min.

which apparently could derive no advantage from an additional supply of water presented to their leaves.

The record of these three species of Celtis, Covillea, and Lycium has been given at length, on account of the importance of establishing beyond doubt the fact that in these plants, which have been taken to represent desert species that retain in structure and habits obvious indications of mesophytic origin, leaf absorption certainly takes place, and apparently as an entirely normal process. We have next to deal with a group of species genetically related, which deport themselves quite differently from members of the first biological group in regard to leaf absorption. As representatives of this second group, species of Parkinsonia, Prosopis, and Acacia were selected, all belonging to the Leguminosae. The record of experiments and their results is such as to admit of statement in few words.

GROUP II.

Parkinsonia Torreyana.

The specimens of *palo verde* employed in this work were seedlings some two months old. One was cut about thirteen hours, the other (number 2) an hour and a half before weighing. After weighing an attempt was made to wet the leaves by repeatedly immersing the seedlings in water. The experiment might fairly have been dropped at this point, since, as it was found impossible to wet them, leaf absorption could hardly be thought of; but as there remained a possibility of some slight absorption where drops of water collected on the surface of the youngest parts, the attempt was continued with number 1, which was repeatedly immersed during a period of something over three hours.

As seen from Table X this seedling, so far from gaining by absorption of water presented to it, actually lost 1.8 per cent. of its weight in three hours and thirteen minutes, its surface having remained almost entirely unwetted, so that loss of water was possible during the whole, or nearly the whole, of this period. Seedling number 2 was allowed to dry, after an unsuccessful series of attempts to wet its surface. Its loss of weight, as might be expected, was greater than that of number 1.

If these results are compared with those of November 1 and 9, derived from similar experiments with shoots of *Parkinsonia micro-*

TABLE X.

PARKINSONIA TORREYANA. SEEDLINGS. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Conditions
1	Dec. 31	9:32 A. M.	0.961		
		12:45 P. M.	0.944	1.8 loss	After repeatedly immersing in water
2		9.37 A. M.	0.886		After drying, following repeated attempts to wet the surface
		12:52 P. M.	0.855	3.5 loss	

phylla and *P. Torreyana*, the conclusion must be drawn that the species of Parkinsonia represented here either absorb no water, or at most an exceedingly small quantity, through their leaves. Before making the experimental test it was thought that the fresh, rapidly transpiring leaves of seedlings might exhibit a capacity for absorption not shown by those of older plants, but this has not proven to be the case.

Prosopis velutina.

Work on the mesquite was carried on at intervals for a number of weeks in January, February, and March, the material first employed being obtained from mature specimens, while in the later experiments seedlings were used. Of specimens taken from mature plants only the leaves were immersed in water. In some cases the upper surface resisted wetting, while in others both surfaces were easily wetted. This was followed, as indicated by some increase of weight, by absorption of water in limited quantities. The seedlings which were employed in subsequent experiments remained unwetted in all cases when they were immersed in water, and in spite of the fact that two of the specimens had been left to dry as much as forty-two hours and showed the effects of this treatment before immersion, there is no evidence that they absorbed any water whatever.

It is apparent, then, that as long as the leaves of the mesquite are perfect and resist wetting they absorb no water, even after drying for some time, but that they may absorb more or less after they have become old and can be wetted. It is very questionable, to say the least, whether in the latter case this process has any physiological significance. It would seem that in the mesquite, as in the *palo verde*, adaptations to xerophytic conditions have been carried so far in the direction of preventing excessive transpiration that leaf absorption, as a normal process, does not take place.

Acacia constricta.

A series of experiments with this species was carried out, but it was found unfavorable for exact results, owing in part to the fact that its leaflets become tightly closed after wetting, thus rendering it difficult to secure perfect drying of the surface without overexposure and consequent uncertainty as to the true weight. Accordingly, the conviction that the data obtained were unreliable led to their rejection. For this second group, therefore, we are restricted to the positive results obtained from Parkinsonia and Prosopis, which exhibit either no capacity or very slight capacity for leaf absorption, so long as the leaves are in perfect condition and normally active.

GROUP III.

This third group includes representatives of a number of genera much modified in form and structure, and differing among themselves in their methods of meeting desert conditions. Several of these are more commonly seen without than with leaves, photosynthesis then taking place in their green shoots; while others, more dependent on leaf activity, are commonly in a leafless condition during a large part of the year, pushing out new leaves promptly when conditions are favorable, and dropping them again when they become adverse, as is seen particularly in the case of Fouquieria.

Holacantha Emoryi.

Of this peculiar shrub a small branch with leaves was cut and left several hours to dry. At the end of this time it was still fresh, with no indication of wilting. After weighing it was wet for two hours and thirty-nine minutes, after which it was weighed again, the weight remaining unchanged. Leaving the shoot now to dry until the next day, and then wetting it for four hours and twelve minutes, there was a gain in weight of only 0.5 per cent. Part of the same shoot, destitute of leaves, was treated in the same way, and, after wetting four hours and eleven minutes, also showed a gain of barely 0.5 per cent. of its former weight. These results indicate on the part of this species capacity for leaf absorption so inconsiderable that it may be neglected.

Koerberlinia spinosa, a closely related species, agrees with Holacantha as far as observations have yet been made. Only leafless

branches have been obtainable, but these, as in the preceding species, are green, and for a large part of the year the plant has no other organ of photosynthesis. So far, then, as present evidence goes, absorption through leaves or internodes is not to be predicated of either of these plants.

Zizyphus lycioides.

After the preliminary experiments already recorded, very little satisfactory material for the study of this species was obtainable, as the plant cast its leaves and remained bare until after the period of study was concluded. From observations made early in the year, however, it appears that leafless shoots of Zizyphus do not absorb water in appreciable quantity, but that leafy shoots have considerable absorptive capacity, indicating that it is the leaves and not the internodes through which absorption takes place.

Fouquieria splendens.

Leafy shoots of the *ocotillo*, as shown by Table XI, absorb considerable water when wet for some time after drying. As in various other cases, the loss of weight on drying the shoots after wetting is considerably more rapid than the preceding gain by absorption.

TABLE XI.

FOUQUIERIA SPLENDENS. *January 1905.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Conditions
1	Jan. 26	12:00 M.	1.614		In each case loss followed drying and gain followed wetting the sp-eci mens during the periods indicated in the time column.
	27	10:00 A. M.	1.582	1.9 loss	
	28	11:40	1.664	5.2 gain	
		3:20 P. M.	1.598	4.0 loss	
	30	1:02	1.518	5.0 "	
		3:28	1.530	0.8 gain	
		4:09	1.523	0.5 loss	
	31	4:15	1.490		
	Feb. 1	1:32	1.585		
2	Jan. 26	2:31 P. M.	4.214		
	27	10:15 A. M.	4.112	2.4 loss	
	28	11:45	4.059	1.3 loss	
	30	2:04 P. M.	4.363	7.5 gain	
		3:04	4.255	2.5 loss	
		4:02	4.197	1.4 "	
	31	11:42 A. M.	3.761	10.0 "	
		2:45 P. M.	3.840	2.1 gain	
		3:45	3.798	1.1 loss	

It appears, then, that for this biological group, which includes a number of plants for the most part unrelated systematically, no general rule can be formulated regarding leaf absorption. The experiments go to show that Holacantha and Koerberlinia hardly absorb at all, while Fouquieria is certainly capable of absorbing considerable quantities of water.

GROUP IV.

The only representatives of the cacti that have been studied thus far are two species of Opuntia, *O. Engelmanni* and *O. versicolor*. A number of specimens of each species were selected after a prolonged drouth, the results of which were plainly seen in their much shrunken condition, very favorable, it would seem, for the demonstration of absorption if this ever takes place. As the material was rather bulky the large balances were employed, a terminal joint in each case being severed and weighed; but there is no reason to doubt the substantial accuracy of the results.

As shown by Tables XII and XIII, *Opuntia Engelmanni* did not in any case gain more than 0.6 per cent. of its original weight, even when immersed in water upwards of 45 hours, and it is safe to conclude from this result, drawn from experiments with a number of specimens, that the species in question does not normally absorb any considerable quantity of water in this way. *Opuntia versicolor*, on the other hand, treated in the same manner, showed

TABLE XII.

OPUNTIA ENGELMANNI. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Conditions
1	Dec. 3	10:15 A. M.	82.360		In each case gain followed wetting and loss followed drying during the periods indicated in the time column.
		1:30 P. M.	82.850	0.6 gain	
	5	11:00 A. M.	83.360	0.6 "	
2	6	10:12 A. M.	72.085		
		1:10 P. M.	72.470	0.5 gain	
		3:05	72.080	0.5 loss	
3		10:39 A. M.	131.750		
		1:33 P. M.	132.290	0.4 gain	
		3:20	131.760	0.4 loss	

TABLE XIII.

OPUNTIA VERSICOLOR. *December 1904.*

No.	Date	Time	Weight in grams	Loss or gain per cent.	Conditions
1	Dec. 3	10:30 A. M.	16.390		
		1:55 P. M.	16.770	2.3 gain	See Table XII
	5	11:11 A. M.	16.780	0.1 "	
2	6	9:55 A. M.	10.640		
		12:14 P. M.	10.850	2.0 gain	
		3:02	10:630	2.0 loss	
3		10:30 A. M.	8.115		
		12:35 P. M.	8.360	3.0 gain	
		3:10	8.115	2.9 loss	

a gain of 2 to 3 per cent. The specimens most shrunken with drouth were found to absorb water most rapidly.

The rapid loss of water and the curiously close correspondence in each case between the percentages of gain and loss, suggest that in this species it is merely the tubercles that act as organs of absorption, and notwithstanding the fact that the water absorbed is so promptly given off in a dry atmosphere, it appears probable that in a period of frequent light rains the continued absorption of water by the tubercles is precisely the necessary preparation for the development of the young shoot which presently follows. Meantime the different deportment of these two species of Opuntia as regards amounts of water absorbed, corresponding as it does with a marked difference in size of their tubercles, suggests the desirability of a more extended comparison of these structures in different cacti with reference to their capacity for absorption and the physiological value of the process.

GROUP V.

A discussion of the annuals and partly herbaceous perennials that have been referred to a fifth biological group, many of which, structurally at least, are not to be thought of as characteristic desert plants, does not fall within the limits of the present study. As already stated, as many of them as have been studied agree in promptly absorbing water when it is presented to their leaves and internodes, which, however, is given off so rapidly in dry air that it hardly seems possible that its absorption is of any utility. *Cf.* Table I, Encelia and Sphaeralcea.

SUMMARY.

From the preceding observations and experiments, in which woody plants were chiefly employed, it has been seen that certain species of desert plants of southern Arizona absorb water presented to their leaves and internodes, while others do not. The species represented in the vicinity of the Desert Botanical Laboratory may be divided into several biological groups, based primarily on the water relation, of which leaf absorption is a phase. Thus, in the first group, including shrubs, which retain well marked mesophytic tendencies, leaf absorption is characteristic. Members of the second group, more distinctively xerophytic in various structural particulars, are incapable of leaf absorption during their period of normal activity. The third group, decidedly xerophytic, but including species of widely different structure and habits, exhibits corresponding differences in regard to subaerial absorption, which takes place in some of its representatives and not in others. The fourth group, including cacti which are assumed to represent the extreme type of xerophytes, also exhibits interesting differences in size and structure of the tubercles by means of which water is absorbed. Finally, members of a provisional fifth group, which in habit and structure are nearer than any other others to the mesophytes of moist temperate regions, absorb water largely, but very quickly give it up again.

It may be doubted, perhaps, whether this classification, based on biological relations, has in itself any permanent value, but meantime it serves to express and emphasize what is apparently no mere theoretical conception, but a simple historical fact, namely, that differences of habit on the part of these desert plants, as well as the structural adaptations with which they are correlated, have become established step by step together, during the long period of geographical changes through which the land they now occupy has been passing. A discussion of the physiological significance of the facts which have been brought out does not fall within the province of this paper.

DESERT BOTANICAL LABORATORY,
Tucson, Arizona.

NEW SPECIES OF CALIFORNIAN PLANTS.

ALICE EASTWOOD.

(WITH TWO FIGURES)

Zygadenus exaltatus, n. sp.—Bulb large, pear-shaped, covered with brownish, membranous coats, about 10^{cm} long, and half as wide: radical leaves forming a conspicuous bunch sheathing the base of stem, 6^{dm} or more long, 2^{cm} wide, veins prominent, midrib conspicuous on lower part of leaf, less so above, glabrous except for the short, rather thick cilia on the margin: stem tall and stout, hollow, $7–8^{dm}$ high, 1^{cm} in diameter at base, leafy to the inflorescence: upper leaves merging into the bracts, lower cauline with broad clasping base, $3–4^{dm}$ long and as broad as the radical leaves: inflorescence paniculate, $2–3^{dm}$ long, the upwardly spreading branches varying in length at different stages of development, the lower branches generally bearing only staminate flowers, the perfect flowers principally borne on the main stem above the branches; staminate racemes with peduncles shorter than the bracts; bracts attenuate; bractlets white, membranous, longer or shorter than the slender pedicels, ovate-attenuate: perianth 17^{mm} in diameter, outer divisions sessile, elliptical, obtuse, the gland 2^{mm} from the base with parallel veins below forming a margined claw, veins on the upper part proceeding from the teeth of the gland, branching; inner divisions of the perianth with claw 2^{mm} long, 1^{mm} wide, the gland oblong, obtuse, veins as in the outer division; filaments broadening towards the base, 5^{mm} long, attached to base of perianth, anthers oblong, becoming explanate in age: fruit becoming 2^{cm} long, including the rostrate styles, tapering a little more at base than at summit.

Type collected by *F. E. Blaisdell* at Prindle's ranch, above Mokelumne Hill, Calaveras County, California, at an altitude of 425^{m}, in April 1900. The other specimens in the Herbarium of the California Academy of Sciences are Amador, California, May 1886, *M. K. Curran* (specimen with root); Soda Creek, Tulare County, *C. A. Purpus*, June 1896, no. 1549; Hindeman's Trail over Coyote Pass, Tulare County, California, July 19, 1903, collected by myself. I also saw it on the trail on the way to Little Kern. In habit of growth and

size of bulb it is related to *Z. paniculatus*, but it has flowers much larger and all the floral organs differently shaped. It is probably the largest species of Zygadenus known. It is probable that there is no *Z. paniculatus* on the western slope of the Sierra Nevada.

Silene deflexa, n. sp.—Stems several from a creeping rootstock, about 2^{dm} high, erect, glandular-puberulent especially above: radical leaves spatulate, $1–2^{cm}$ long including the margined petioles, rather thick in texture, obtuse; cauline leaves 3–4 pairs, the uppermost very small, not more than 3^{mm}, the lowest oblanceolate to oblong, obtuse, 2^{cm} long, connate-clasping and nodose at base: flowers solitary in the lower leaf-axils, pedicels erect and close to stem, flowers curved-deflexed in anthesis, erect in fruit; terminal flowers few, cymose, pedicels capillary, $7–12^{mm}$ long, generally shorter than the flowers; calyx narrowly cylindrical in flower, enlarging and breaking apart with the expanding capsule, 10-ribbed, 9^{mm} long, divisions rounded at apex, oblong, sometimes uneven, membranously margined, 1.5^{mm} long; petals with the claws united tc the stamens and the stipe of the ovary at base, woolly, gradually enlarging to the blade, not auricled, blade 4-cleft into linear lobes, the two middle 2^{mm} long, 0.5^{mm} wide, the two lateral narrower and shorter, appendages oblong, reaching the base of divisions, retuse with one side pointed; stamens and styles apparently not surpassing the petals, the latter three and the upper thick part of the ovary splitting into three valves, lower part of ovary thin cylindrical, all together 4^{mm} long; stipe 1^{mm} long and almost as thick: seeds suborbicular, brown, strophiolate.

Type collected in the Hudsonian Zone above the lakes, Canyon Creek, Trinity County, California, by *Vernon Baily*, August 25, 1899.

It is related to *S. Lemmoni*, but differs in the foliage, the shorter filaments and styles, the close inflorescence, and the differently shaped floral organs. It really resembles that species only in having the flowers pendent and the blades of the corolla with four divisions.

Silene lacustris, n. sp.—Cespitose from creeping rootstocks, slender, erect, $1–1.5^{dm}$ high, glandular-puberulent throughout especially the inflorescence, flowering from the lowest axils: radical leaves narrowly oblanceolate, acute or obtuse, tapering to a long margined petiole, all together 2^{cm} long; cauline leaves 2–3 pairs, linear, obtuse, connate-clasping at base, $1–2^{cm}$ long, $1–2^{mm}$ wide:

calyx broadly cylindrical, 1^{cm} long, thin, with ten purple nerves, the divisions rounded, 2.5^{mm} long, 2^{mm} wide; petals with claws woolly and cohering round the thick stipe, gradually broadening to the membranous laciniate auricles, 4^{mm} at top, blades purple, 2-cleft with rounded divisions, the lateral teeth short or none, the appendages bifid and laciniate, 1^{mm} long; stamens and styles exserted; ovary oblong, 4^{mm} long: fruit unknown.

Type collected by the author at Monarch Lake near Mineral King, Tulare County, California, July 21, 1903.

This species belongs to the group of high mountain Silenes, including *S. Grayi*, *S. Watsoni*, and *S. Suksdorfii*. In appearance and shape of leaves it most closely resembles the first, but differs from this and the others in the broader auricles, and the bifid, laciniate appendages of the corolla.

Silene pacifica, n. sp.—Perennial, with thick woody rootstocks; stems generally several, erect, 4.5^{dm} high, viscid throughout, especially the inflorescence, nodes prominent: leaves rather thin, radical and lower cauline oblanceolate to obovate or elliptical, tapering at base and decurrent on the long petiole; blade 5–6^{cm} long, 2–3^{cm} wide, slightly ciliate, sparingly pubescent, obtuse or acute; petioles margined, dilated and sheathing at base; cauline leaves connate-clasping at base, 4–5^{cm} long, the uppermost leaves lanceolate, sessile: flowers verticillate in the axils or cymose on short peduncles, pedicels 0.5–2^{cm} long, the longest equaling the longest floral leaves: calyx truncate at base, tubular, becoming somewhat turbinate with the enlarging capsule, very viscid, prominently green or purplish veined, the divisions deltoid, obtuse or acute, 4^{mm} long, green with white or purplish membranous margins, entire calyx 1.5^{cm} long; corolla claret color, the claws of the petals white or tinged with claret, 1.5^{cm} long, attenuate at base and broadening at truncate summit to 4^{mm}, exserted 5^{mm}, blade deeply cleft, each part entire, laciniate, or bilobed, the prominent divaricate teeth on each side almost as long as the divisions, more than 1^{mm}, appendages laciniate-dentate, 1.5^{mm} long; stamens monadelphous at base, encircling the stipe and pubescent, glabrous above, varying in length: pod 11^{mm} long, the tips of the three valves stellately reflexed and often splitting into five or six over the calyx when the seeds are ripe; stipe stout: seeds light brown, slightly pitted, reniform, 2^{mm} wide.

Type collected by the author along the south side of Rodeo Lagoon, not far from the ocean, Marin County, California, July 4, 1905. The species seems to be isolated, as the number of plants is small and it is not elsewhere to be found in the region. It is also in danger of extermination on account of the improvements that are now going on in the vicinity of the military post.

This is most closely related to *S. grandis* Eastwood from Bodega Head, likewise a maritime species. It differs in having claret-colored flowers, a differently shaped calyx, the simpler inflorescence, thinner and different leaves, and entire lack of the velvety pubescence so noticeable on *S. grandis*. A smaller and more slender plant.

Horkelia mollis, n. sp.—Stems several, ascending from the sheathed caudex, red-purple, villous with fine silky spreading hairs, about 2^{dm} in height: radical leaves $6–9^{cm}$ long, less than 1^{cm} wide, the petiole less than half the entire length, often with a few scattered simple leaflets near the base; leaflets crowded towards the top, pinnately divided but apparently pedate on account of the lower divisions surpassing the upper, the divisions linear-spatulate, $3–4^{mm}$ long, finely villous; stipules adnate for 8^{mm}, the free tips filiform-attenuate, about 4^{mm} long, villous; cauline leaves similar but with petioles becoming shorter as they ascend, stipules often incised and always broader than those on the radical leaves: flowers corymbose-capitate, terminating the stems, a few solitary ones or few-flowered clusters in the axils of the upper cauline leaves; hypanthium campanulate, 5^{mm} long, the bractlets linear, about as long as the subulate sepals; petals yellow, the blades broadly spatulate, 1^{mm} wide, a little longer, slightly shorter than the linear claw; stamens 15 in three rows; ovaries 5–20, glabrous, the slender styles tuberculate at base.

The type is 4405 of *Carl F. Baker's* distribution, collected by *Culbertson* July 19, 1904, at Hockett's Meadows, Tulare County, California. In the herbarium of the California Academy of Sciences are specimens of the same, collected by the author along Volcano Creek in the same region, July 17, 1903.

This species probably is most closely related to *Horkelia campestris* (Jones) Rydberg. A comparison with a duplicate of the type of the latter shows *H. mollis* to be a larger, more villous plant, the appendages of the hypanthium longer, the divisions more pointed, the petals more exserted and with blades orbicular and claws more pronounced. In general the flowers are larger.

STYRAX CALIFORNICA **fulvescens**, n. var.—Shrub a meter or so high, with stiff divaricate branches; older stems gray-black,

younger white or tawny with dense stellate tomentum: leaves orbicular-cordate, the apex obtuse or abruptly acuminate, generally slightly longer than broad, 3–6^{cm}, both surfaces stellate-tomentose, the upper less than the lower, the fulvous hairs often outlining the veins on lower surface; petioles 5–10^{mm} long: flowers 1–3, cymose, pendent, the pedicels as long as the peduncles; calyx campanulate, cuneate at base, the margin truncate but marked with 5–6 short obtuse scattered teeth, densely clothed with white or rufous tomentum; stamens 12, almost equaling the petals, attached almost the entire length of the corolla tube, filaments glabrous, ribbonlike, anthers with cell divisions white, the connective yellow, thick; style thick, broadening at base, lower half tomentose, stigma 2-lobed, surpassing the corolla.

The type of this variety was collected by the author May 17, 1904, near the Painted Cave Ranch in the Santa Inez Mountains back of Santa Barbara, California. Mr. *T. S. Brandegee* collected the same in the same mountains probably near San Marcos Pass in 1888. There is a specimen also of what seems the same collected by *J. G. Lemmon* near San Bernardino, May 1878. Near the head of Mission Creek a second collection was made by the author. This bush grew in the shade and was taller and less rufous than the others on the open hills.

This differs from the typical *S. californica* in the broader, rounder leaves, heart-shaped at base, the much denser stellate tomentum, and the general prevalence of rufous hairs especially on the calyx.

Diplacus calycinus, n. sp.—Suffrutescent, viscid-arachnoid throughout, the young stems light brown, branching diffusely: leaves elliptical to oblong, narrowed at each end, apex obtuse, base cuneate, margin revolute, entire or somewhat sinuate-denticulate, upper surface glabrous, often viscid, lower tomentose and viscid, 2–6^{cm} long, 1–2^{cm} wide; petioles very short, revolutely margined, woolly at junction: flowers axillary, the peduncles 5–7^{mm} long; lower part of fruiting calyx cylindrical, 2^{cm} long, 5^{mm} in diameter, 5-ribbed, upper half dilating abruptly to thrice the diameter of the lower, with 5 strongly keeled almost equal divisions 7^{mm} long, 3^{mm} wide at base when folded, 1^{mm} at the rounded apex, total length of calyx 3.5^{cm}; corolla light yellow, the tube curved, uniformly slender for 1.5^{cm}, dilating above, the divisions having a spread of 1.5–2^{cm}, exserted from the calyx.

This was first collected by Mr. *T. S. Brandegee* in Kaweah Canyon, Tulare County, California, July 26, 1892. The type is 4407 of *C. K. Baker's* distribution collected by *Culbertson* in the south fork of Kaweah River, 1800^{m} altitude, July 22, 1904.

This species is distinguished from allied species by the peculiar foliaceous calyx described above. The corolla in the dried specimens cannot be satisfactorily described, as in both collections the specimens are a little old.

Orthocarpus Copelandi, n. sp.—Stems about 1^{dm} high, simple or divaricately branched, minutely scabrous with short, curved hairs: lowest leaves narrowly linear-lanceolate, obtuse, 3–4^{cm} long; upper on main stem as long but twice as broad; uppermost on branches falcate, alternate or opposite: spike short and dense; lowest bracts green, the middle division like the broadest leaves, the lateral divisions spreading and very slender, about one-third as long as the middle; upper bracts shorter and broader, elliptical, rose-tipped: calyx thin and membranous, becoming globular-inflated, pink with green ribs, cleft half in front, deeper in the back, villous with short gland-tipped hairs, 7^{mm} long, 4^{mm} broad, with divisions triangular attenuate; corolla minutely glandular, 13^{mm} long, galea straight, obtuse, rose-color, ciliate, 6^{mm} long, lower lip yellow, the three sacs inflated somewhat, 5^{mm} long, middle tooth much larger than the other two: capsule bright brown, 5^{mm} long, 3.5^{mm} wide, obovate with obcordate apex, with few (apparently only two) seeds.—FIG. 1.

Collected on Mount Eddy, August 18, 1903 at an altitude of 2130^{m} by Dr. *Edwin Bingham Copeland*, in whose honor it is named. It is a beautiful species related to *O. imbricatus* and that group which contains so many closely related species. *H. E. Brown's* number 449 from the north side of Mt. Shasta is the same but very immature.

Veronica Copelandi, n. sp.—Perennial from slender, running rootstocks, about 1^{dm} high, simple, glandular-villous throughout: leaves five or six pairs, crowded on the lower part, sessile, oblong-elliptical, entire, acute, veinless, 1–1.5^{cm} long, 4–8^{mm} wide: racemes sometimes becoming 8^{cm} long, 5–15-flowered, the highest leaves often with one or two axillary flowers; bracts lanceolate, the lowest opposite, others alternate, shorter than the pedicels; peduncles 1–2^{cm} long, sometimes scarcely apparent; pedicels filiform, 5^{mm} long, a small bractlet immediately below the calyx appearing like another

FIG. 1.—*Orthocarpus Copelandi* Eastw.

sepal: sepals 4, oblong-ovate, obtuse, 3^{mm} long; corolla purple, glabrous, 9^{mm} across, the three larger divisions orbicular, entire, 4^{mm} in diameter, the smallest ovate-obtuse, 3^{mm} wide; stamens exserted, 4^{mm} long, filiform, anthers obtuse and obtusely sagittate at base, 1.5^{mm} long; stigma exserted from the opening bud, obscurely bilobed, style 7^{mm} long, filiform at base, flattening and slightly broadening towards the apex: capsules becoming almost twice as long as the calyx divisions, broadly oblong, 5^{mm} long, 3.5^{mm} wide, emarginate, the lobes and sinus obtuse; style persistent.—FIG. 2.

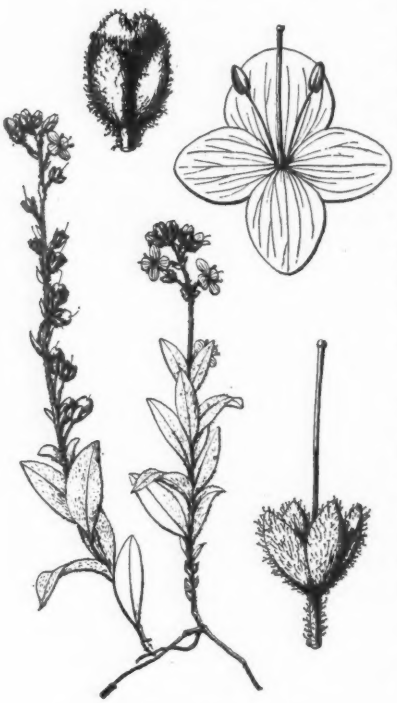


FIG. 2.—*Veronica Copelandi* Eastw.

This was collected on Mount Eddy at an elevation of 2500^{m} by Dr. *Edwin Bingham Copeland*, August 18, 1903, distribution of *C. E. Baker*, 1903. no. 3931. It is near to *V. Cusickii* Gray, differing in pubescence, shape of leaves and sepals, and a larger and more open-spreading corolla.

Erigeron decumbens, n. sp. —Stems several, from slender creeping rootstocks, decumbent or ascending, 1–1.5^{dm} high, scabrous and somewhat canescent with short appressed hairs which are glandular at base (under a lens): leaves oblanceolate to spatulate, sessile, obtuse, apparently veinless, 5–15^{mm} long, 3–5^{mm} wide, with pubescence similar to the stems: heads few, rayless, 7^{mm} high, terminating short branchlets, which are leafy near the junction with the stem and have a few scattered minute bracts on the upper part; scales of the involucre in four series, glandular-puberulent, outer ones small, reflexed-spreading, inner green-tipped, ribbed, membranous at base,

linear-lanceolate, acute, 6^{mm} long: corolla yellow, tubular, abruptly narrowed 1^{mm} above the base, the border consisting of five short, obtuse, incurved teeth; style branches exserted, the hairy tips very short: akenes slightly hairy at top; pappus simple, barbellulate, as long as the corolla.

Collected by Dr. *Edwin Bingham Copeland* on Mount Eddy, Siskiyou County, California, at an altitude of 1400^{m}, August 17, 1903. It belongs to the group which includes *E. miser* Gray, as well as many species described by Dr. E. L. Greene in *Flora Franciscana*, p. 394; but it agrees with none.

Erigeron Copelandi, n. sp.—Cespitose from an underground, branched caudex, covered with black, scale-like, imbricated bases of old petioles: radical leaves spatulate, subcanescent, with closely appressed very short pubescence; petioles equaling or longer than the blades, together 1–3^{cm} long, 4–8^{mm} wide, the petioles dilated and closely imbricated at the reddish-purple base: stems 1-flowered, 5–10^{cm} high, sparsely leaved with narrow linear or linear-oblanceolate leaves 5–10^{mm} long, becoming minute and bract-like on the glandular-puberulent upper part which is like a peduncle: heads about 6^{mm} high exclusive of the numerous, very narrow, lilac to violet rays, which are 5^{mm} long; scales of the involucre in three series, glandular-puberulent, the outermost shorter, clothed with some scattered hairs, innermost linear-attenuate, sparsely ciliate, green-ribbed, membranously margined, about 5^{mm} long; disk flowers numerous, yellow, 2.5^{mm} long, narrowed 1^{mm} above the base, glandular on the lower part, the border of five short acute incurved teeth: pappus upwardly barbellulate, simple, that of the ray flowers shorter than that of the disk, none as long as the corolla; akenes clothed with upwardly spreading hairs; stamens exserted in some flowers, pistils in others; fertile and sterile flowers in the same head, ray-flowers sterile.

Collected on Mt. Eddy, Siskiyou County, California, at an altitude of 1250^{m} by Dr. *Edwin Bingham Copeland*, in whose honor it is a pleasure to name this pretty plant. It is related to *E. pygmaeus* Greene and others of that group, but differs from all in caudex, pubescence, leaves, and heads.

Chrysopsis gracilis, n. sp.—Stems slender, simple, 3^{dm} high, loosely and sparingly villous-arachnoid, terminated by 2–4 cymose heads: leaves thin, linear-lanceolate, narrowly acuminate, 3–4^{cm}

long, 6^{mm} wide, sessile, the upper surface somewhat dotted, lower surface arachnoid (under a lens): peduncles with pubescence like the stem but also somewhat viscid, bracts few, narrowly linear: involucral scales in about 5 ranks, the outer narrowly linear- attenuate, the others lanceolate, acute, tipped with a green and glandular spot, below yellowish, chartaceous, keeled, the innermost sometimes tinged with purple and considerably surpassing the others; heads with about 15 flowers, rayless: corolla straw color, about as long as the pappus, trumpet-shaped, gradually narrowed to the base, border with acute teeth, 1^{mm} long; style branches filiform, exserted, twining around each other at base; pappus thick, with an outer shorter row, barbellulate; akenes flat, villous, white.

Collected on Mount Eddy at an elevation of 2225^{m} by Dr. *Edwin Bingham Copeland*, August 17, 1903.

This comes very near *C. Breweri* Gray, of which it may prove to be only a variety. It differs however, in the simple instead of much branched stems, more finely arachnoid pubescence, and leaves of different outline. The involucral scales are the most distinctive; in *C. Breweri* they are attenuate and not keeled; in *C. gracilis* they are broader, acute, keeled, conspicuously green-tipped and glandular; the corollas are paler and the pappus not so rough.

Psilocarphus tenuis, n. sp.—Sparingly clothed with long loose white woolly hairs; stems filiform, erect or ascending, 3–5^{cm} high, with few slender divaricate branches: leaves oblong to elliptical, 5–10^{mm} long, 3^{mm} wide, veiny and submembranous, mucronate at apex, the base of the opposite leaves connate-clasping: heads in the forks and at the ends of the branches, the involucral leaves 4, ovate-oblong, folding over and almost concealing the flowers within, texture similar to the other leaves: fertile flowers few or many, completely enclosed by the obliquely-cuneate bracts, these gibbous, veiny, membranous, slightly woolly, 2.5^{mm} long, the apex orbicularly truncate or concave, the exserted membranous tips brownish, conspicuous, generally curved upwards: akenes shortly stipitate, narrowly obovate, 1^{mm} long: sterile flowers few, the corolla attenuate to the base, divisions reddish-brown.

Type collected at Monterey, California, by Mrs. *Joseph Clemens*, July 1905. What seems to be the same, but too young for certainty, was collected by the author at Bakersfield, Kern County, California, April 4, 1893, and at Kaweah, Tulare County, California, April 27, 1895.

This seems most distinct from all the other species in having the involucral leaves almost closing over the flowers, the peculiar concave or truncate top to the bracts enclosing the fertile flowers, and in the more veiny and membranous foliage, less woolly pubescence, and more slender habit.

Senecio Millikeni, n. sp.—Stems tall, glabrous, hollow, ribbed, paniculately branched, the slender virgate branches leafless in the lower part: leaves linear-lanceolate, narrowed at both ends, with acute apex, sessile base, margin dentate with small uneven obtuse teeth, the lower 12^{cm} long, 2.5^{cm} wide, diminishing upwards: panicle thrysiform, the peduncles and pedicels slender, bracts and bractlets attenuate, equaling or longer than the slender pedicels: heads 1^{cm} high, bracteate at base, the involucre 5^{mm} high, with glabrous scales tipped at apex with a tuft of tomentum; rays 6, 3-toothed, 7^{mm} long, style exserted 3^{mm}; disk flowers 7^{mm} long, the acute triangular teeth of the corolla slightly granular, stamens exserted but style branches surpassing them: akenes glabrous; pappus soft and abundant, about as long as the corolla.

Type collected in Natural Bridge Meadows, Tulare County, California, by *Culbertson*, Aug. 10, 1904, *C. F. Baker's* distribution 4268. It is named in honor of Mr. Culbertson's assistant.

This belongs to the polymorphous group of which *S. triangularis* was the first described. It differs from all in the narrowed bases of the leaves, the thyrsiform inflorescence, and the smaller heads.

San Francisco, California.

BRIEFER ARTICLES.

NOTES ON NORTH AMERICAN GRASSES. VI.

SYNOPSIS OF TRIPSACUM.

TRIPSACUM L., Syst., Ed. 10, 2: 1261. 1759.

A GENUS of grasses confined for the most part to North America. The type species is *T. dactyloides* L.

KEY TO SPECIES.

Staminate spikelets all sessile or nearly so, outer glume coriaceous; spikes single or 2- to 3-digitate. Section DACTYLOIDES.

- Blades 4 to 5^{cm} wide, pubescent on upper surface . . . *latifolium*
- Blades mostly less than 2^{cm} wide
  - Blades 1 to 3^{mm} wide, involute . . . . . *floridanum*
  - Blades 1 to 2^{cm} wide, flat
    - Sheaths glabrous, blades glabrous except sometimes along the midrib above . . . . . *dactyloides*
    - Sheaths more or less hispid, or sometimes nearly glabrous, blades hispid on upper surface *dactyloides hispidum*

Staminate spikelets with one of the pair sessile, the other pedicelled, outer glume membranaceous; pistillate spikes branched, forming a fascicle. Section FASCICULATA.

- Sheaths hispid . . . . . *pilosum*
- Sheaths glabrous except the lowermost, or hispid only at the throat
  - Blades 3^{cm} or more in width, glabrous . . . . *fasciculatum*
  - Blades 2^{cm} or less in width, pubescent on upper surface
    - 1.5 to 2^{cm} wide, flat or folded, culms robust . *lanceolatum*
    - 5 to 10^{mm} wide, more or less involute, culms slender . . . . . *Lemmoni*

Tripsacum latifolium, n. sp.—Planta robusta, vaginis glabris vel apice pubescentibus, laminis amplis, ad 4.5^{cm} latis, 70^{cm} longis, planis, supra pubescentibus subtus scabris vel glabrescentibus, spiculis sterilibus geminis sessilibus, 3–4^{mm} longis, oblongis, obtusis vel breviter acutis.

Culm robust, 1^{cm} in diameter, glabrous; sheaths glabrous or pubescent towards apex; blades ample, as much as 70^{cm} long and 4.5^{cm}

wide, pubescent above, minutely papillate-scabrous or glabrescent beneath, scabrous-ciliate on the margin; ligule very short, scarcely 3^{mm} long, fimbriate; spikes 1 to 3, similar to *T. dactyloides* but more slender, pistillate section 2 to 3^{mm} wide, staminate spikelets sessile or nearly so, 3 to 4^{mm} long, outer glume coriaceous, oblong, rounded at apex, scabrous, ciliate on marginal keels, rather minutely striate with about ten nerves.

The type specimen was collected by *H. von Tuerckheim* at Cubilquitz, Dept. Alta Verapaz, Guatemala, alt. 350^{m}, Jan. 1902, no. 8333. The only other specimen I have seen was collected by *C. Thieme* at San Pedro Sula, Dept. Santa Barbara, Honduras, alt. 500^{m}, March 1887, no. 5595^{B}. Both specimens are in the National Herbarium (Herb. John Donnell Smith).

The species is well distinguished from the other species with sessile staminate spikelets by its broad pubescent leaves.

TRIPSACUM DACTYLOIDES (L.) L., Syst., Ed. 10, **2**:1261. 1759.—*Coix dactyloides* L., Sp. Pl. **2**:972. 1753.—Usually glabrous throughout except the upper surface of the blades along the midrib near the base. This and sometimes a considerable portion of the upper surface of the blades may be sparsely pilose. The specimens from Florida and along the Gulf Coast are usually pilose in this way, or occasionally the pubes cence may extend to the young sheaths of the branches. The more pubescent forms connect the species with the following subspecies, which occurs in Mexico. The terminal spikes are usually in digitate clusters of two to three, while the axillary spikes may be single. Sometimes, especially in Texas, the terminal spikes are also single (*T. dactyloides monostachyum*) (Willd.) Gray, Man. 616. 1848. *T. monostachyum* Willd., Sp. Pl. **4**:202. 1805. Type locality "Carolina meridionali."

Southern New England to Florida and Texas, mostly near the coast; but extending inland west to west Texas, and north to Nebraska, Iowa, southern Illinois, and eastern Tennessee.

If the spike is single the pistillate portion is cylindrical; if the spikes are two or three, the pistiilate portions are flattened on the inner surfaces so that all together they form a cylinder, and the lower are more or less peduncled.

TRIPSACUM DACTYLOIDES **hispidum**, n. subsp.—Laminae supra hispidae; vaginae hispidae vel glabrescentes.

The staminate flowers are less chartaceous than is usual in *T. dactyloides*.

Mexico and southward. San Luis Potosi, rocky hills, Las Canoas,

Pringle 3811 (type); Jalisco, Rio Blanco, *Palmer* 509; City of Mexico, *Holway* 8; Lower California, El Taste, *Brandegee*, Nov. 1, 1902; Trinidad, Botanical Garden Herbarium 3303; Central Paraguay, *Morong* 675.

This form connects *T. dactyloides* with *T. lanceolatum*. In some specimens the upper spikelet of the staminate pair is somewhat pedicelled. *T. dactyloides* and possibly some of the other species may occur widely distributed in South America. Information on this point is desired.

TRIPSACUM FLORIDANUM Porter, Contr. Nat. Herb. **3**:6. 1892. PORTER'S herbarium name was published by Dr. VASEY in his monograph of the grasses of North America. Type locality "Florida (*A. P. Garber*) and Texas (*G. C. Nealley*);" duplicate type in National Herbarium. *T. dactyloides floridanum* Beal, Grasses **2**:19. 1896. There are no specimens of this species from Texas in the National Herbarium, nor are there any so labeled by Dr. VASEY; consequently the Texas locality given above is uncertain and is probably incorrect.

Our specimens are all from the vicinity of Miami, Florida, *Garber* 454, June 1877 (type); *Pollard & Collins* 272, April 1898; *Eaton* 530, Dec. 1903; *Hitchcock*, March 1903.

Distinguished from *T. dactyloides* by its smaller size and much narrower leaves.

TRIPSACUM FASCICULATUM Trin.; Ascherson, Bot. Zeit. **35**:521. 1877.—Well distinguished by its ample glabrous leaves, which are as much as 6.5^{cm} wide and 70^{cm} long, resembling leaves of Indian corn (*Zea mays* L.). Plant glabrous throughout; spikes branched, forming a fascicle; staminate portion slender and more or less flexuous, the spikelets 5 to 6 mm long and broadest near the top.

The name first appears in the second edition of STEUDEL'S Nomenclator **2**:712, as *Tripsacum* "fasciculatum Trin. Mpt. Mexico. *T. dactyloides* Schlecht. in Linnaea VI." The latter name is a *nomen nudum*, as is also *T. fasciculatum* Trin. in Steud. Gram. **1**:363, and in Ruprecht, Bull. Acad. Brux. **9**:243. The first description appears to be by ASCHERSON[1] in 1877, Bot. Zeit. **35**:525, where a specimen from "Pr. Hacienda de la Laguna (Schiede)" is designated as the type. FOURNIER, Mex. Gram. 69. 1881, includes the name without description and cites the following specimens: Hacienda de la Laguna (*Schiede* 947); Orizaba

[1] ASCHERSON had previously mentioned the species and given a brief description as follows: "Diese Art besitzt Blätter von der Breite der Maisblätter, und die zahlreichen, schlaffen, männlichen Inflorescenzzweige, deren Aehrchen kleiner als bei *T. dactyloides* sind, erinnern ebenfalls an *Euchlaena*." (Verh. bot. Ver. Pr. Brandenb. **17**:79. 1875, in a footnote to an article on *Euchlaena mexicana*.)

(*Bourgeau* 3138); Mirador (*Liebmann* 549); Zacuapan pr. Jalapa (*Galeotti* 5796); Arumbaro (*Galeotti* 5844). The BOURGEAU and LIEBMANN specimens are in the National Herbarium; also *Brade* 16174, from Costa Rica.

TRIPSACUM LANCEOLATUM Rupr.; Fournier, Mex. Gram. 68. 1881.—Leaves mostly 1 to 2^{cm} broad, pubescent on the upper surface; staminate flowers 7 to 9^{mm} long, spindle-shaped, often rather abruptly narrowed above the middle.

Mexico. Sonora, Guadaloupe Cañon, International Boundary Commission, 2035; Durango, *Palmer* 537; Oajaca, Villa alta, *Liebmann* 547; Lower California, Sierra de San Francisquito, *Brandegee* 6, Sept. 1899; Jalisco, between Huejuquilla and Mesquitec, *Rose* 3570. In addition to these specimens in the National Herbarium, FOURNIER gives the following: Inter Victoria et Rio Blanco (*Karwinsky*); Borrego prope Orizaba (*Botteri* 1213 in herb. VAN HEURCK); Mirador (*Schaffner*); Tacubaya (*Schaffner* 41 in herb. FRANQUEVILLE); Secus Amnem in herbosis pr. Pedregal (*Bourgeau* 444); Aguas Calientes (*Hartweg* 252). *Liebmann* 547 is also cited by FOURNIER and it is upon this specimen that I have based my identification of the species. FOURNIER'S description does not apply in all respects to the plants which I have included under this species. He states that the culms are pilose, which is not true of any of the specimens I have seen. Neither are both staminate spikelets pedicelled, as he describes.

The name first appears in Plant. Hartw. Addenda, p. 347. In the body of the work (p. 28) no. 252 is listed without description as *T. dactyloides* "in saxosis, Aguas Calientes." In the addenda this is corrected as follows: "n. 252 est species a Tripsaco dactyloide distincta, T. lanceolata, Ruppr. ex cl. Rupprecht in Litt." FOURNIER (*l. c.*) cites *T. lanceolatum* Rupr. in Benth. Pl. Hartw. 247. Under the circumstances I think HARTWEG'S no. 252 from Aguas Calientes should be considered as the type of *T. lanceolatum* rather than KARWINSKY'S specimen, the first cited by FOURNIER.

FOURNIER cites as a synonym of this "*T. acutiflorum* Rupr. mss. in herb. Petrop." Under the rules of the recent code *T. acutiflorum* was not published. FOURNIER (*l. c.* 69) also mentions without description, var. *β monostachyum* from San Luis Potosi (*Virta* 1447). I have not seen this specimen.

TRIPSACUM PILOSUM Scribn. & Merr., Div. Agrost. Bull. 24:6. 1901. —Type locality Mexico. "Collected on the road between Colotlan and

Bolaños, State of Jalisco, 2841 *J. N. Rose*, September 7, 1897." Specimen in National Herbarium.

The preceding species, together with this and the following, form a rather closely connected series. The type of *T. pilosum* is distinguished by the strongly papillate-hirsute sheaths, and the blades pubescent upon both surfaces, but these characters are much less marked in some of the specimens which agree with the type in other particulars.

I have referred here the following specimens: Jalisco, Rio Blanco, *Palmer* 508; Cañon near Guadalajara, *Pringle* 2623, and hills near Guadalajara, *Pringle* 2611; San Luis Potosi, limestone ledges, Tinamel, *Pringle* 3993; and San Jose Pass, *Pringle* 3447.

TRIPSACUM LEMMONI Vasey, Contr. Nat. Herb. **3**:6. 1892. Type locality, "Huachuca Mountains, Arizona (*J. G. Lemmon*)." Type specimen in National Herbarium. *T. dactyloides Lemmoni* (Vasey) Beal Grasses **2**:19. 1896.

Plant glabrous throughout except the lowermost sheaths, which are more or less hispid. The leaves are long and narrow, 5 to 10^{mm} wide, and in herbarium specimens inrolled at the margins.

In addition to the type specimen I have included two Mexican specimens, Jaral, Gebirgsthäler, *Schumann* 1718, and Jalisco, Mountains near Guadalajara, *Pringle* 2610. These two specimens have the spikes digitate instead of fascicled as in Arizona specimen, but the latter has the lateral spikes in ones or twos.—A. S. HITCHCOCK, *U. S. Dept. Agric., Washington, D. C.*

CURRENT LITERATURE.

BOOK REVIEWS.

Vegetable foods.

THIS well-known work of MOELLER on this subject,[1] first put out about twenty years ago, has played an important part in connection with the increasing use of the microscope as a practical instrument for recognizing vegetable sub stances in a more or less finely divided state. Many changes have taken place within this period, not only in the art of substitution and adulteration, which is as alert and progressive as any that might be mentioned, but also in matters of legitimate commerce. Hence a thoroughgoing reworking of the field has been made necessary. In connection with this service, Prof. A. L. WINTON, now of the Connecticut Agricultural Experiment Station, a pupil of MOELLER, has furnished very important aid in the form of excellent figures as well as text.

The scope of the work is in general indicated by the title and those articles here treated are with few exceptions used as food for man or beast, the term food being defined so as to include such articles as flavoring agents as well as tea, coffee, and cacao. Under the appropriate headings those substances are also described and figured which occur as impurities, substitutions, and adulterations. Since it often happens that condiments are also official drugs, many chapters have a strong pharmaceutical interest. A few articles are considered which have their chief significance as drug products, e. g., sandal wood, guarana, cubebs, cola, salep, and calamus.

In the treatment of the individual articles, the book is distinguished by a concise and exact statement of the features, gross and microscopic, characterizing the structures concerned, dimensions frequently cited giving definiteness to terms of size.

As valuable as the excellent text, are the numerous drawings illustrative of it. A large number are original, many being by Dr. WINTON. A bibliography of the most important articles written on each subject closes the consid-ation. One novel feature among the illustrations is seen in the gross pictures of the leaves discussed. Here a direct print is made on a sensitive surface, using the leaf itself as an opaque object. This method has been successfully used before by a number of authors with various objects and here the result is in general successful. Frequently a very considerable amount of detail has

[1] MOELLER, JOSEF, Mikroskopie der Nahrungs- und Genussmittel aus dem Pflanzenreiche. Zweite gänzlich umgearbeitete und unter Mitwirkung A. L. Winton's vermehrte Auflage. 8vo. pp. xvi+599. *figs.* 599. Berlin: Julius Springer. 1905. *M* 18; geb. *M* 20.

been obtained in the half tone reproductions of these so-called "autophotograms."

The revision of this important work has again brought it to the front and promises to continue it as one of the valuable literary aids to the investigator of pure foods.—RODNEY H. TRUE.

ALMOST simultaneously with the foregoing has appeared in this country a similar compendium by the same team; this time the pupil leads and the master is the collaborator.[2] The general plan and purpose of Dr. WINTON'S weighty volume are similar to those of Dr. MOELLER'S. The fact that it is in English will give it a sale that the German book could not hope to attain among the food commissioners and inspectors and the official chemists, to whom at present such a work makes its chief appeal. By reason of the existing agitation in this country on the subject of pure foods and drugs, the enforcement of existing laws, and the imminence of new and more exacting legislation, this publication is peculiarly timely. The botanical features are on the whole reasonably accurate, especially the anatomy, which is most fundamental. The definitions in the glossary are not always above criticism, and accuracy would not have rendered them less practical. The illustrations are numerous and good, particularly the original ones. A strong foreign flavor pervades the whole book, showing the impress of the work of MOELLER, yet curiously his second edition is not cited in the bibliography. The arrangement of material, analytic keys, lists of adulterants, and the suggestions as to diagnosis are sure to be of great practical service in the new campaign against sophistication by unscrupulous manufacturers and dealers.—C. R. B.

MINOR NOTICES.

Cryptogamic flora of Brandenburg.[3]—This monumental work begins its seventh volume with the first fascicle of the Ascomycetes. Its character and scope are so well known that the announcement of its publication and contents will suffice to secure the orders of all who concern themselves with this group. Hemiasci are treated by G. LINDAU; Saccharomycetineae by P. LINDNER; Protascineae by G. LINDAU; Exoascaceae, Erysiphaceae, Perisporiaceae, Macrothyriaceae, and Aspergillaceae by F. NEGER; Onygenaceae, Elaphomycetaceae, Terfeziaceae, and Tuberaceae by P. HENNINGS.—C. R. B.

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[2] WINTON, A. L., The microscopy of vegetable foods, with special reference to the detection of adulteration and the diagnosis of mixtures. With the collaboration of Dr. JOSEF MOELLER. Imp. 8vo. pp. xvi+701. *figs.* 589. New York: John Wiley & Sons. 1906. $7.50.

[3] Kryptogamenflora der Mark Brandenburg, Band 7, Heft 1. Pilze. Von P. HENNINGS, G. LINDAU, P. LINDNER, F. NEGER. 8vo. pp. 160. *figs.* 17. *pls.* 8. Leipzig: Gebrüder Borntraeger. 1905. *M*1.50. (Not sold separately.)

NOTES FOR STUDENTS.

What is a species?—The many discussions as to what is a species have resulted in a general appreciation of the facts that species are not all of equal rank, that they are distinguished by more or less arbitrary characters, and that although many species are real natural groups of individuals, many others are simply arbitrary groups, associated for the sake of convenience. After reviewing the various methods of distinguishing species, KUPFFER[4] concludes that no method will apply in all cases, that all methods are of importance, and that when the several methods are used conjointly, little difficulty is experienced.

KUPFFER then turns to the methods of KÖLREUTER, based upon the sterility of hybrids, as a method which has not been used to the extent its merits warrant. Sterility of the hybrids being presumably due to defective germ-cells, he depends for his measure of sterility upon the condition of the pollen, basing his method upon the fact pointed out a few years ago by JENCIC[5] that viable pollen swells immediately upon the introduction of water, while the sterile pollen remains shrunken, and that this capacity of the normal pollen to swell is retained for many years in herbarium materials (more than 50 years in Viola, *fide* KUPFFER).

Although the author recognizes that considerable sterility of the pollen has been observed in many "good" species, he has himself never found a pure species in which more than a few (ein Paar) per cent. of the pollen grains remained shrunken, the implication being that the reported instances would bear further consideration.

After examining a number of species and their hybrids, especially among the Violaceae, he concludes that when a supposed hybrid shows much less fertility of the pollen than its supposed parents, it is not a *necessary* but a *sufficient* proof (1) that the supposed hybrid is truly a hybrid, and (2) that its parents belong to distinct species.

Application of this method is then made with interesting results to forms of Potentilla, Viola, Thymus, etc., which have puzzled the systematist.—GEORGE H. SHULL.

Propagation of grain rust.—Further comments by Dr. JAKOB ERIKSSON[6] on the question of the origin and distribution of the rust-diseases of plants have recently been presented to the botanical public through separata. The author has not essayed so much to put forth new facts, as to bring together and review those recently published, in so far as they bear upon his mycoplasm theory, giving especial attention to adverse criticisms.

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[4] KUPFFER, K. R., Kölreuters Methode der Art Abgrenzung nebst Beispielen ihrer Anwendung und einigen allgemeinen Betrachtungen über legitime and hybride Pflanzenformen. Acta Hort. Bot. Univ. Imp. Jurjevensis **6**:1–19. 1905.

[5] JENCIC, Untersuchungen des Pollens hybrider Pflanzen. Oesterr. Bot. Zeits. **50**:1, 41, 81. 1900.

[6] ERIKSSON, J. Zur Frage der Entstehung und Verbreitung der Rostkrankheiten der Pflanzen. Arkiv för Botanik **53**:1–54. 1905.

He maintains that after taking into consideration the studies and observations of MARSHALL WARD and PLOWRIGHT in England; MCALPINE and COBB in Australia; BOLLEY, HITCHCOCK, and CARLETON in North America; BARCLAY in India; KLEBAHN, DIETEL, SCHROETER, and MAGNUS in Germany; LAGERHEIM in Sweden, and others, the wintering of the uredo-bearing mycelium, or of the uredospores, so as to be a source of infection for the coming season, has not been proven. The evidence, chiefly as brought forward by KLEBAHN, to show that the first appearance of the rust in spring can often be accounted for by uredospores being carried long distances by the wind, is reviewed, and the conclusion reached that this is an assumption based on no direct evidence and highly improbable.

The author then enters upon the vital part of the subject and discusses the mycoplasm theory and its recent criticism, especially that which has been most ably presented by KLEBAHN and MARSHALL WARD. After an extended examination of the works of these authors, he finds that his theory has not been affected. He directs attention to a report by BIFFEN of recent experiments in hybridizing wheat carried on at Cambridge, England, in which the appearance of rust on the plants can best be explained by assuming that the mycoplasm of certain varieties was transmitted through the pollen to the resulting hybrid. —J. C. ARTHUR.

Gynodioecism.—CORRENS[7] has presented a second[8] report on the gynodioecism of *Satureia hortensis* and *Silene inflata*, giving full confirmation of his earlier conclusion that the pistillate form produces only, or mostly, pistillate offspring when fertilized, as it must be, by the bisporangiate form. If the pistillate form is a mutant from the bisporangiate and differs from the latter by the possession of a distinct hereditary unit, as suggested by Burck,[9] all the seeds produced by a pistillate plant are of hybrid origin, and the observed facts would be best explained as a case of dominance of the newly risen character over the older. In Satureia this dominance (?) is complete, but in Silene the offspring of the pistillate plants were pistillate in only 87–93 per cent., the rest being bisporangiate. Although this behavior looks very much like Mendelian inheritance, a number of cases are cited in which quite contradictory results have been obtained, so that while the author states it as a law that each sex has a *tendency* to transmit its own sex form, he does not look upon this as dominance in the Mendelian sense.—GEORGE H. SHULL.

An ear of corn.—The origin of such economic plants as wheat and maize, which have a wide distribution in cultivation but are unknown in the native

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[7] See BOT. GAZETTE **39**:304. Ap. 1905.

[8] CORRENS, C., Weitere Untersuchungen über die Gynodioecie. Ber. Deutsch. Bot. Gesell. **23**:452–463. 1905.

[9] BURCK, W., Die Mutation als Ursache der Kleistogamie. Recueil Trav. bot. Néerl. **1–2**:95 *sqq.* 1905.

state will doubtless always be an interesting subject for speculation. The most satisfactory hypothesis for the origin of maize, and that which has been until this time rather generally accepted, derives it from the teosinte (Euchlaena). It has been thought that the ear was formed by an abnormal coalescence of the pistillate spikes of that plant. The ease with which maize and teosinte may be crossed gives strong support to the theory that they are nearly related.

An altogether different view of the origin of the pistillate spike of maize is presented by MONTGOMERY[10] and much evidence is given in its support. His hypotheses are that the ear of corn is the homologue of the central spike of the staminate inflorescence; and that the progenitor of maize was a much branched plant, bearing only terminal branched inflorescences of bisporangiate flowers. The chief support of these hypotheses is derived from abnormal development of pistillate and bisporangiate flowers in the staminate inflorescence, and *vice versa*. A number of photographs show these abnormalities and *fig. 14* represents a plant, denuded of its leaves, showing that the same number of internodes intervene between the central axis and the ear as are found between the ear and the tassel. Nothing in this new interpretation of the pistillate spike of maize need lessen the conviction of its near relationship with Euchlaena.—GEORGE H. SHULL.

The laws of inheritance.—CORRENS[11] has published a lecture on the laws of inheritance which presents in a very satisfactory manner the recent advances which have been made in this discipline. He would include in hybridization every union between two germ-cells having one or more different character-units. The laws of dominance and of the purity of the parental gametes are illustrated from his own experiments on Urtica, Mirabilis, and Zea, and emphasis is given to the fact that these two laws are absolutely unrelated to each other, and that reference to them jointly as Mendel's Law is misleading.

Latency is considered at some length, but the present state of knowledge of this subject leaves much to be desired. He makes a proper distinction between latency in the sense of invisibility, and *true* latency in which there is actual inactivity of a unit that may be changed at times from a passive to an active state.

Regarding the relation between MENDEL'S and GALTON'S laws, he holds with DARBISHIRE,[12] that both are correct and the antagonism only apparent, due to the different manipulation of the data.

CORRENS still maintains that sex is fundamentally unlike the unit-characters which behave in accord with MENDEL'S laws. Touching on xenia and tel-

[10] MONTGOMERY, E. G., What is an ear of corn? Popular Sci. Monthly **68**: 55–62. *figs. 14*, Jan. 1906.

[11] CORRENS, C., Ueber Vererbungsgesetze. 8vo. pp. 43. *figs. 4*. Berlin: Gebr. Borntraeger. 1905.

[12] DARBISHIRE, A. D., On the supposed antagonism of Mendelian to biometric theories of heredity. Mem. and Proc. Manchester Lit. and Philos. Soc. **49**. no. 6. 1905. 19 pp.

egony, he holds that neither exists in the strict sense, namely that ids may escape from the germ-cells to produce modification in the surrounding maternal tissues, or to be transferred thence into subsequent germ-cells.—GEORGE H. SHULL.

Heterostyly in Primula.—The inheritance of heterostylism in Primula has been investigated by BATESON and GREGORY,[13] who find that there is general agreement with Mendelian expectation, the short style being dominant over the long style. A second character, a yellow flush in the center of the flower, which was found associated with an "equal-styled" condition, also proved to be Mendelian and capable of being transferred by crossing to the short-styled form. The investigation showed that whenever the yellow flush occurs in a combination in which the long style would be expected, the styles do not develop beyond the level of the anthers, thus forming the "equal-styled" type. Several aberrant results were observed, the most noteworthy being a case in which a single plant indicated a different composition of its germ-cells, according as it was used as the pollen-parent or pistil-parent.—GEORGE H. SHULL.

Asparagus rust.—SMITH[14] has published a final account of his investigation of the asparagus rust in California. One of the most important results of his work is the demonstration of the fact that the spores of this rust depend upon dew for the moisture required for germination. The more detailed account of the water relation of this rust was published in this journal.[15] This discovery suggested certain practical methods of controlling the rust, such as planting the rows with the wind and preventing weeds and other plants or trees from forming a windbreak close about the asparagus field. In other words, the field should be well ventilated. The bulletin will long continue to be the standard work of reference for information upon the subject.—E. MEAD WILCOX.

Potato scab.—HENDERSON[16] has recently published the results of his studies of the methods of control of the potato scab. He found that rolling the potato tubers in sulfur did not prevent the scab, and this is in accord with results secured by other investigators. Formalin and corrosive sublimate gave equally good results with the factor of safety in use in favor of the formalin. If treated potatoes were planted in soil in which "scabby" potatoes had grown the previous season, the scab appeared in spite of the treatment. This emphasizes the necessity of preventing new ground from becoming infected with the disease by planting none but healthy tubers.—E. MEAD WILCOX.

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[13] BATESON, E., and GREGORY, R. P., On the inheritance of heterostylism in Primula. Proc. Roy. Soc. London B. **76**: 581–586. 1905.

[14] SMITH, R. E.—Asparagus and asparagus rust in California. Bull. Calif. Exp. Stat. 165: 1–99. *figs. 1–46.* 1905.

[15] SMITH, R. E., BOT. GAZETTE **38**: 19–43. *figs. 1–21.* 1904.

[16] HENDERSON, L. F., Potato scab. Bull. Idaho Exp. Stat. 52: 1–8. 1906.

Nuclear division in Ascomycetes.—GUILLIERMOND[17] has continued his studies on nuclear division in the Ascomycetes, which support in all essentials the conclusions of HARPER and contravene those of MAIRE (except as to Galactinia), though they are perhaps not irreconcilable with them. However, his descriptions are not so detailed as those of HARPER in his last paper on Phyllactinia, especially as it relates to the centers of spindle formation. In this paper GUILLIERMOND discusses chiefly the mother-cells of the asci and secretion. The species studied comprise *Pustularia vesiculosa*, *Aleuria cerea*, *Peziza rutilans*, *P. Catinus*, and *Galactinia succosa*. —B. M. DAVIS.

Soil waters.—CAMERON and BELL show[18] that as a rule the various mineral constituents of the soil solutions exist in sufficient concentration for the growth of crops, and that the magnitude of the concentrations is *practically the same for all soils*, because, generally speaking, soils contain all the common rock forming minerals, some of each species presenting its surfaces to the solvent action of the soil water; and on account of hydrolysis of the solutes this solvent action is continuous. The paper strongly supports the previous work of the Bureau of Soils which has been so much criticised, often on *a priori* grounds.—C. R. B.

Non-infection by rusts.—*Erysiphe graminis* has a number of biologic forms which are confined to special hosts. Thus conidia from the form on wheat will not infect barley and that on oats will not infect wheat. SALMON[19] has recently shown that the reason of the non-infection is not due to inability on the part of the conidia to germinate, but because the haustoria cannot establish relations with the cells of the host plant.—B. M. DAVIS.

Endoparasitic adaptation.—SALMON[20] shows that *Erysiphe graminis* adapts itself readily to an endophytic life. When spores are sown on a wound in oats or barley the mycelium ramifies in the intercellular spaces and haustoria are abundantly produced. Conidiophores develop profusely and perfect conidia where they arise on a free surface; and they even break through a weak barrier when they develop in intercellular spaces.—C. R. B.

Greening of seeds.— ERNST[21] finds that during the ripening of the fruit of *Eriobotrya japonica* the seeds become green, quite independent of light, by reason of the greening of the amyloplasts. The process begins at the plumule of the

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[17] GUILLIERMOND, A., Remarques sur la karyokinèse des Ascomycètes. Ann. Mycol. 3:343–361. *pls. 10–12.* 1905.

[18] CAMERON, F. K., and BELL, J. M., The mineral constituents of soils. U. S. Dept. Agric., Bur. Soils Bull. 30. pp. 70.

[19] SALMON, E. S., On the stages of development reached by certain biologic forms of Erysiphe in cases of non-infection. New Phytol. 4:217. 1905. *pl. 5.*

[20] SALMON, E. S., On endophytic adaptation shown by *Erysiphe graminis* DC. under cultural conditions. Phil. Trans. Roy. Soc. London B. 198:87–97. *pl. 6.* 1905.

[21] ERNST, A., Das Ergrünen der Samen von *Eriobotrya japonica*. Beihefte Bot. Centralbl. 19[1]: 118–130. *pl. 2.* 1905.

embryo and progresses from this region to the inner and outer faces of the cotyledons. Complete greening, however, only follows illumination.—C. R. B.

The nucleus and secretion.—In the nectar glands on the stipules of the *Vicia Faba*, according to STOCKARD,[22] the nucleus does not give out granular material directly to the cytoplasm, but it transmits a substance which results in the formation of granules. Changes which occur in the cytoplasm during secretion seem to be controlled by the nucleus.—CHARLES J. CHAMBERLAIN.

Black rot of cabbage.—HARDING, STEWART, and PRUCHA[23] find much of the cabbage seed in the market contaminated with *Pseudomonas campestris*, which may survive and become a source of infection to seedlings. They advise sterilizing seed by soaking for fifteen minutes in $HgCl_2$ 1:1000, or in formalin 1:240.—C. R. B.

Movement of diatoms, etc.—JACKSON suggests[24] that the evolution of oxygen is the true cause of movements of diatoms, desmids, oscillaria, nostoc, etc. He has been able to imitate the movements by those compressed tablets and bits of aluminum of proper shapes which evolve gas.—C. R. B.

Anatomy of Claytonia.—A study of this genus by THEO. HOLM forms one of the Memoirs of the National Academy,[25] where it may be overlooked by botanists. It contains some of the accumulating details which a master hand must some day correlate.—C. R. B.

Apothecia of lichens.—GERTR. P. WOLFF[26] through some studies on the development of the apothecia in a number of lichens argues against LINDAU'S terebrator theory of the function of the trichogynes in lichens.—B. M. DAVIS.

Intercellular ducts.—The intercellular spaces in the cotyledons of Leguminosae function at the beginning of germination as conducting canals for aleurone which becomes dissolved and diffuses through them.[27]—C. R. B.

Mustiness.—The peculiar musty odor acquired by damp straw or corn is due, according to ROUSSEU,[28] to the oospora form of *Streptothrix Dassonvillei* and not to other of the fungus flora found thereon.—C. R. B.

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[22]STOCKARD, CHAS. R., The structure and cytological changes accompanying secretion in the nectar glands of *Vicia Faba*. Science **21**:204–5. 1906.

[23]HARDING, H. A., STEWART, F. C., PRUCHA, M. J., Vitality of the cabbage black rot germ on cabbage seed. N. Y. Agr. Exp. Sta. Bull. 251: 177–194. 1905.

[24]JACKSON, D. D., Movements of diatoms and other microscopic plants. Jour. Roy. Mic. Soc. **1905**: 554–7.

[25]HOLM, THEO., Claytonia, a morphological and anatomical study. Mem. Nat. Acad. Sci. **10**: 27–37. *pl. 1, 2.* 1905.

[26]WOLFF, GERTR. P., Beiträge zur Entwicklungsgeschichte der Flechtenapothecien. Flora **95**:31. 1905.

[27]JOFFRIN, H., Rôle circulatoire des méats intercellulaires dans les cotylédons des Légumineuses au début de la germination. Rev. Gén. Bot. **17**: 421–2. 1905.

[28]BROCQ-ROUSSEU, Contributions a l'étude des causes qui provoquent l'odeur de moisi des grains et fourrages. Rev. Gén. Bot. **17**: 417–420. 1905.

NEWS.

PROFESSOR J. C. ARTHUR spent the greater part of January at the New York Botanical Garden in a study of Uredineae.

PROFESSOR B. M. DUGGAR has been spending the winter in research at the Botanical Institute at Montpellier, directed by Professor CH. FLAHAULT.

THE *Bulletin* de l'Académie Internationale de Géographie Botanique announces the limitation of leading articles to thirty-two pages. We hope the movement will become general among journals. By proper condensation an author can say all he is entitled to say on one subject in such a space.

DR. JESSE M. GREENMAN spent some six weeks in Yucatan and adjacent Mexico collecting plants for the Field Natural History Museum, of whose herbarium he is assistant curator. He had a violent attack of malarial fever which interfered seriously with his work, but he has returned in good health and with fair collections.

LAST SUMMER after leaving the Vienna Congress, Professor GEORGE F. ATKINSON spent some time in the vicinity of Nice, Paris, and especially in the Jura mountains in the vicinity of Pontarlier, studying the fleshy fungi. He collected over 300 species, made photographic studies, and preserved material for morphological investigation.

THE VIENNA CONGRESS nominated as presidents of the Committee of Organization for the Brussels Congress of 1910 LÉO ERRERA and TH. DURAND. On account of the lamented death of Professor ERRERA the *Association internationale des botanistes* has named Senator Count OSW. DE KERCHOVE DE DEUTERGHEM as his successor. M. ÉMILE DE WILDEMAN has been made general secretary.

MR. J. B. ELLIS, whose taxonomic work on North American fungi is known the world over through his numerous publications and the important sets of *exsiccati* issued by him and Mr. EVERHARDT, died at his home in Newfield, New Jersey, December 30, 1905. A biographical sketch of Mr. ELLIS was published in this journal in November 1890. His herbarium and library have been for some years the property of the New York Botanical Garden.

PROFESSOR WILLIAM WHITMAN BAILEY will retire from the faculty of Brown University at the close of the present academic year. He has been connected with the University for nearly twenty-eight years, twenty-five of them as professor of botany. For some years he has been suffering from ill health and feels it wise not to carry longer the burden of regular classroom work. Yet he will retain close connection with the University, and advise in many of its affairs.

A NEW JOURNAL, *Le Bambou*, has been established by JEAN HOUZEAU DE LEHAIE, Ermitage, Mons, Belgium. The English part of the trilingual prospectus contains some interesting information for our readers, and is at the same time so amusing in its construction and spelling that we reprint part of it.

"Our aim is the facility for botanists and lovers of Bamboo of communicating their studies and desiderata, and exchanging their observations. We claim likewise as design to let better know the horticultural value of these plants and, giving information on the process of culture and on the places from where they kan be obtained, to spread as much as possible their use in parks and gardens. Each number shall contain: 1th a technical part, 2d a practical part.

"The technical part for wohm we can rely on the cooperation of distinghuished botanists wohm names are know from a long time, shall comprise the description of new or little known species, with plates, or cuts, the critical examination of the nomenclature and synonymy and the bibliography.

"These studies shall compose an ensemble which will become a vade mecum necessary to all lovers of Bambusaceae who whish to make serious study. . . .

"Briefly, the classification of Bamboo is still on many points somewhat wavering and the principal design of the technical part is to cooperate to its perfection.

"We will attend with much care to the bibliography: it shall contain not only a list as complete as possible and up to the day of all the works relating to Bamboo in any way; but we ask from our readers to insert in our 'letter box' their demands of books. . . . .

"We hope that our correspondents will be so good as to communicate the tittles of the books on this matter within their knolege.

"The practical part shall contain such advices of culture our essais, began since 1883, entitle us to give; . . . .

"We will successively review these plants noting the peculiarities distinguishing each of them. We will fix the culture, the value, the rational arboricultural use, the edurance to the inclemency of the weather of each of them.

"We will offer in our pages the largest hospitality to the discussions our subscribers and correspondents could wish to hold out, leaving to them the whole responsability of their propositions.

"Our letter box will allow everyone to ask questions and to send responds to offer or to sollicit plants in exchange or to points outs plants they desire to buy. In short we will endeavor to become the *mediator of all the loevers of Bamboo*.

"We will print notices not only in french, but in latin, english, german italian and esperanto, with the faculty of joigning, as the case may be a translation or a summary.

"We wanted that the first number should be entirely of our one penn; not so much to definite the way we wish to adopt, but to sustain alone the responsability of the beginning and to free from all responsability the correspondents who spontaneously offered their instant collaboration. . . . . "